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Ground Water Investigation and Remediation

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Introduction

During 1999, ground water investigations and remediations under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) continued at both the Livermore site and Site 300. LLNL regularly samples and analyzes ground water from areas of known or suspected contamination. Portions of the two sites that contain ground water with concentrations of chemicals of concern are actively investigated to determine the magnitude of the contamination and its source. Remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each study area is developed in consultation with the regulatory agencies and the community. This chapter reviews the distribution of contaminants in ground water, and the progress LLNL has made in removing contaminants from ground water and from the unsaturated zones (soil vapor) at the Livermore site and Site 300.

Livermore Site Ground Water Project

Physiographic Setting

The general topography of the Livermore site is described in Chapter 1. The Livermore Valley ground water system is a sequence of semiconfined aquifers in which ground water moves downslope from the valley uplands toward the east-west axis of the valley. It then flows generally westward toward the southwest portion of the basin. From there, ground water has historically flowed south into the Sunol Valley Ground Water Basin. The largest quantities of ground water are pumped from the central and western portions of the Livermore Valley, where the valley fill is thickest.

The valley fill sediments make up two aquifers: the Livermore Formation and its overlying alluvium. The Livermore Formation averages about 1000 m in thickness and occupies an area of approximately 250 km^2. The alluvium, which is about 100 m thick, is the principal water-producing formation within the valley.

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Hydrogeology

Sediment types at the Livermore site are grouped into four categories—clay, silt, sand, and gravel—based on dominant particle size. Ground water flow beneath the site is primarily in alluvial sand and gravel lenses and channels, bounded by the less permeable clays and silts. The alluvial sediments have been mapped into seven hydrostratigraphic units (HSUs) beneath the Livermore site using data collected over the years. HSUs can be defined as sedimentary sequences whose permeable layers show evidence of hydraulic connection. The HSUs of concern beneath the Livermore site are the Quaternary alluvial deposits of the upper Livermore member of the Livermore Formation (see **Figure 8-1)**. HSUs 1B, 2, 3A, 3B, 4, and 5 contain contaminants that are primarily solvents (Blake et al. 1995 and Hoffman et al. 1998).

Remedial Activities

In 1999, the Livermore site Ground Water Project (GWP) treated more than 1100 ML of ground water, brought new treatment facilities on line, installed wells, conducted hydraulic tests, developed ground water models, published required documents, and maintained close contact with regulatory agencies and the community.

LLNL operated ground water treatment facilities and vapor treatment facilities (VTF) in the TFA, TFB, TFC, TFD, TFE, TFG, TF406, TF518, and TF5475 areas. A total of 69 ground water extraction wells operated at 20 separate locations at an average flow rate of 3.0 ML/day in 1999. A total of three vapor extraction wells operated at two separate locations at an average flow rate of 2846 m^3/day. **Table 8-1** shows the volumes of ground water and soil vapor treated at the facilities and the estimated volatile organic compound (VOC) mass removed from the subsurface during 1999 and since the beginning of the remediation. A graph of VOC mass removal at the Livermore site since 1989 is presented in **Figure 8-2**. Concentrations of remaining VOCs in the fourth quarter of 1999 are depicted as concentration maps in the six HSUs in **Figures 8-3** through **8-8**.

Table 8-2 lists the extraction wells according to the hydrostratigraphic unit in which they are screened and the total flow rate for each treatment area. Together, the ground water and vapor treatment facilities removed approximately 267 kg of VOC mass in 1999. Since operations began, approximately 4247 ML of ground water and almost 0.48 million m^3 of vapor have been treated, and more than 752 kg of VOCs have been removed. The VOC plumes in HSUs 1B, 2, 3A, 3B, 4, and 5 continue to be hydraulically controlled based on trends in ground water chemistry, capture zone analysis, and the total VOC isoconcentration maps (**Figures 8-3** through **8-8**) for each HSU.

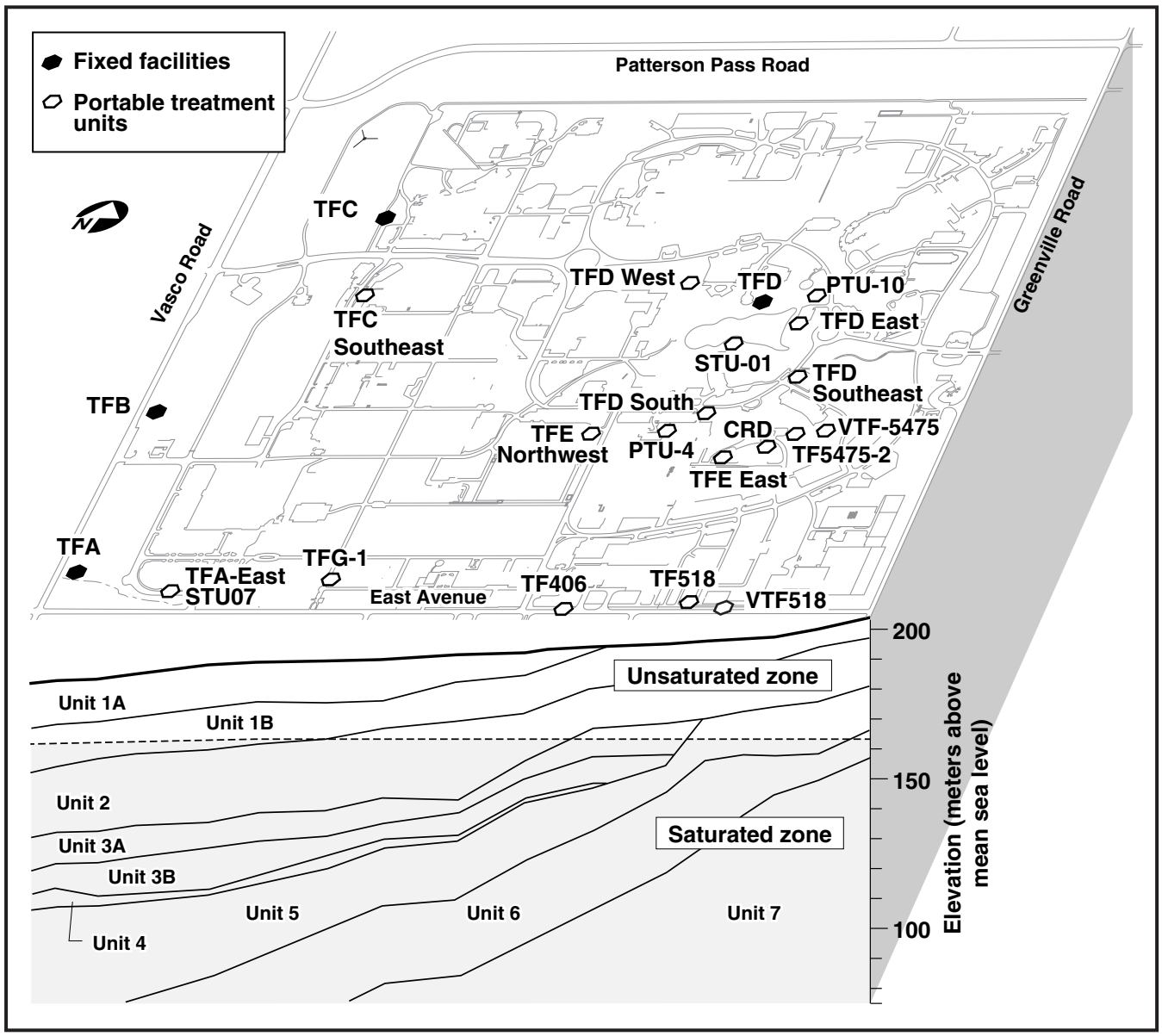


Figure 8-1. Map and cross section of the Livermore site showing hydrostratigraphic units and the locations of the treatment plants.

The numbers and locations of new wells installed in 1999 are shown in **Table 8-3**. Well construction details, well closure data, and results of drawdown tests are provided in the *LLNL Ground Water Project 1999 Annual Report* (Aarons et al. 2000).

Table 8-1. Volatile organic compounds (VOCs) removed from ground water and soil at the Livermore site.

Treatment facility[a]	Startup date	1999		Cumulative total	
		Water treated (ML)[b]	VOCs removed (kg)	Water treated (ML)[b]	VOCs removed (kg)
TFA	9/89	519	14	2,468	123
TFB	10/90	114	7.6	430	38
TFC	10/93	93	9.0	316	32
TFD	9/94	226	88	696	235
TFE	11/96	108	38	201	72
TFG	4/96	10	0.6	38	1.8
TF406	8/96	28	1.0	83	4.2
TF518	1/98	3.6	0.2	14	1.2
TF5475	9/97	0.64	0.4	0.76	2.3
Total		1,102	159	4,247	510
		Soil vapor treated (m^3)	VOCs removed (kg)	Soil vapor treated (m^3)	VOCs removed (kg)
VTF518[c]	9/95	101,834	13.1	418,258	147
VTF5475[c]	1/99	59,274	94.9	59,274	95
Total		161,108	108	477,531	242

a Includes fixed and portable units.

b ML = 1 million liters.

c Vapor extraction facility.

Treatment Facility A

Treatment Facility A (TFA) is a fixed facility that is located in the southwestern quadrant of the Livermore site near Vasco Road and East Avenue (**Figure 8-1**). Ground water is treated using the large-capacity air-stripping system that was installed in June 1997. The VOCs are stripped from the ground water, and the effluent air from the stripper is passed through granular activated carbon (GAC) filters to remove the VOCs. The treated effluent air is then vented to the atmosphere. The California Regional Water Quality Control Board (RWQCB) permits LLNL to treat up to 500 gallons per minute (gpm) of ground water. Treated ground water from TFA is discharged to the Recharge Basin, located about 600 m southeast of TFA on Department of Energy (DOE) property administered by Sandia National Laboratories/California. Since startup of the new system, TFA has not exceeded the 5 parts per billion (ppb) total VOC discharge limit.

Wells at TFA pumped at a combined flow rate of about 1150 L/min and treated 519 ML of ground water containing an estimated 14 kg of VOCs.

Treatment Facility A—East (TFA-East) began operating in September 1999. This facility consists of one extraction well operating at a flow rate of 5.6 L/min. The water is treated at a portable solar-powered treatment unit that discharges its treated water to Arroyo Seco.

One monitor well was installed in the TFA area in 1999 (see **Table 8-3**). Two other piezometer wells were installed as a part of ongoing work at the infiltration study area.

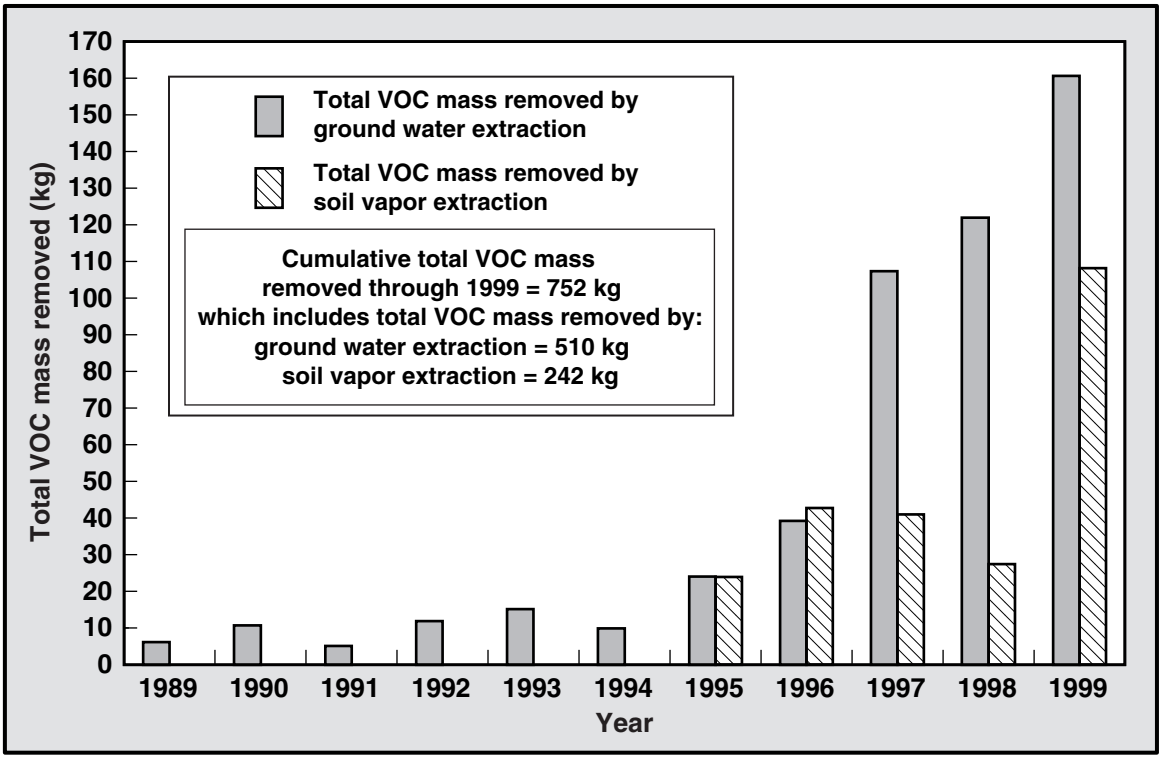


Figure 8-2. Total VOC mass removed from the subsurface of the Livermore site, 1989–1999.

Treatment Facility B

Treatment Facility B (TFB) is located in the west-central portion of the Livermore site. Ground water is treated using the large-capacity air-stripping system that was installed in October 1998. This unit replaced an ultraviolet/hydrogen peroxide (UV/H_2O_2) system that had been in use since 1990. Ground water is also treated for chromium(VI) in an ion-exchange unit during the winter months, based on the current RWQCB

discharge substantive requirements. Wells at TFB pumped at a combined flow rate of about 287 L/min, and treated about 114 ML of ground water containing an estimated 7.6 kg of VOCs. Treated ground water from TFB is discharged into the north-flowing drainage ditch parallel to Vasco Road that empties into Arroyo Las Positas to the north. TFB was in compliance throughout 1999. No new wells were installed at TFB during 1999 (**Table 8-3**).

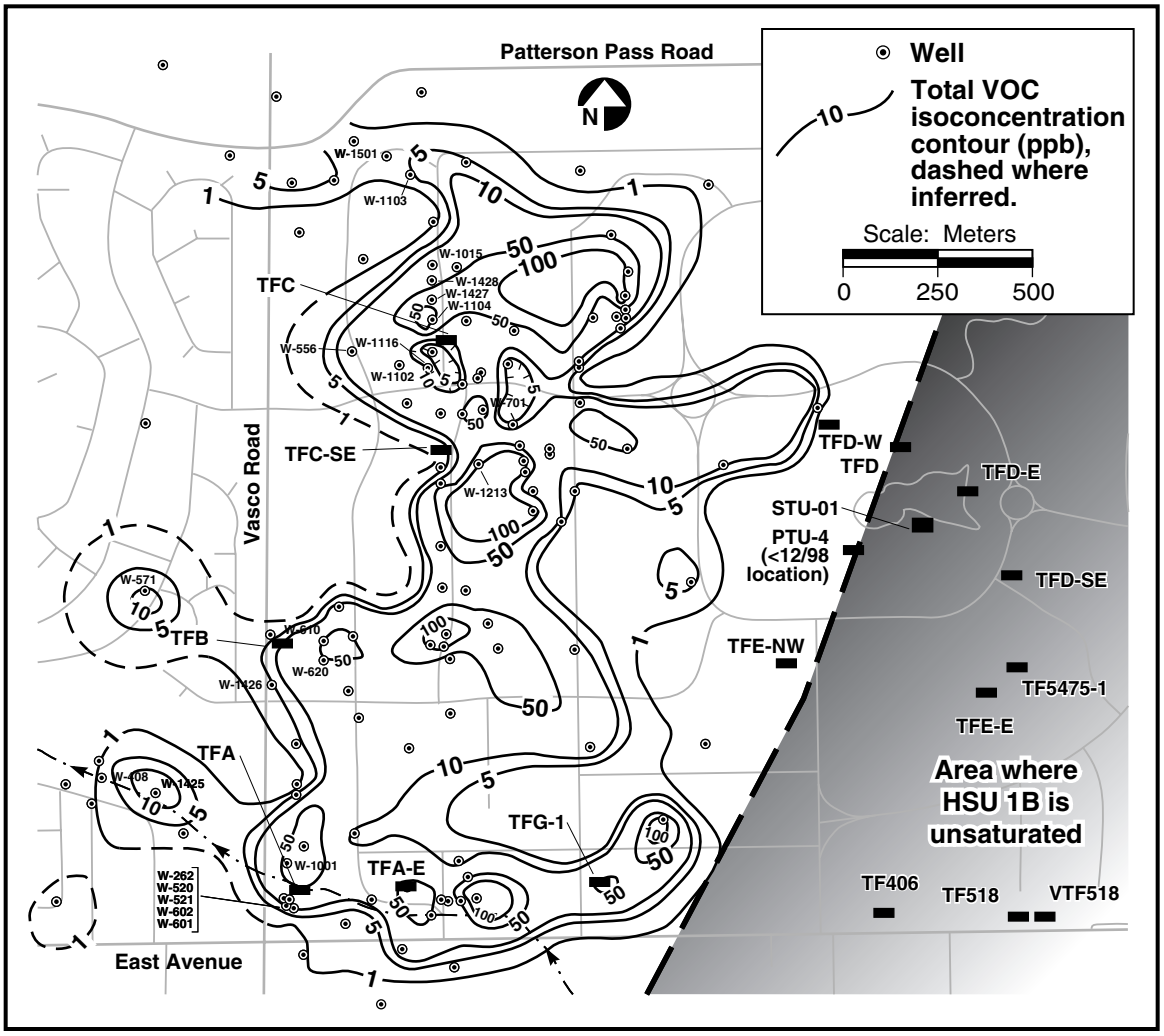


Figure 8-3. Isoconcentration contour map of total VOCs within HSU 1B.

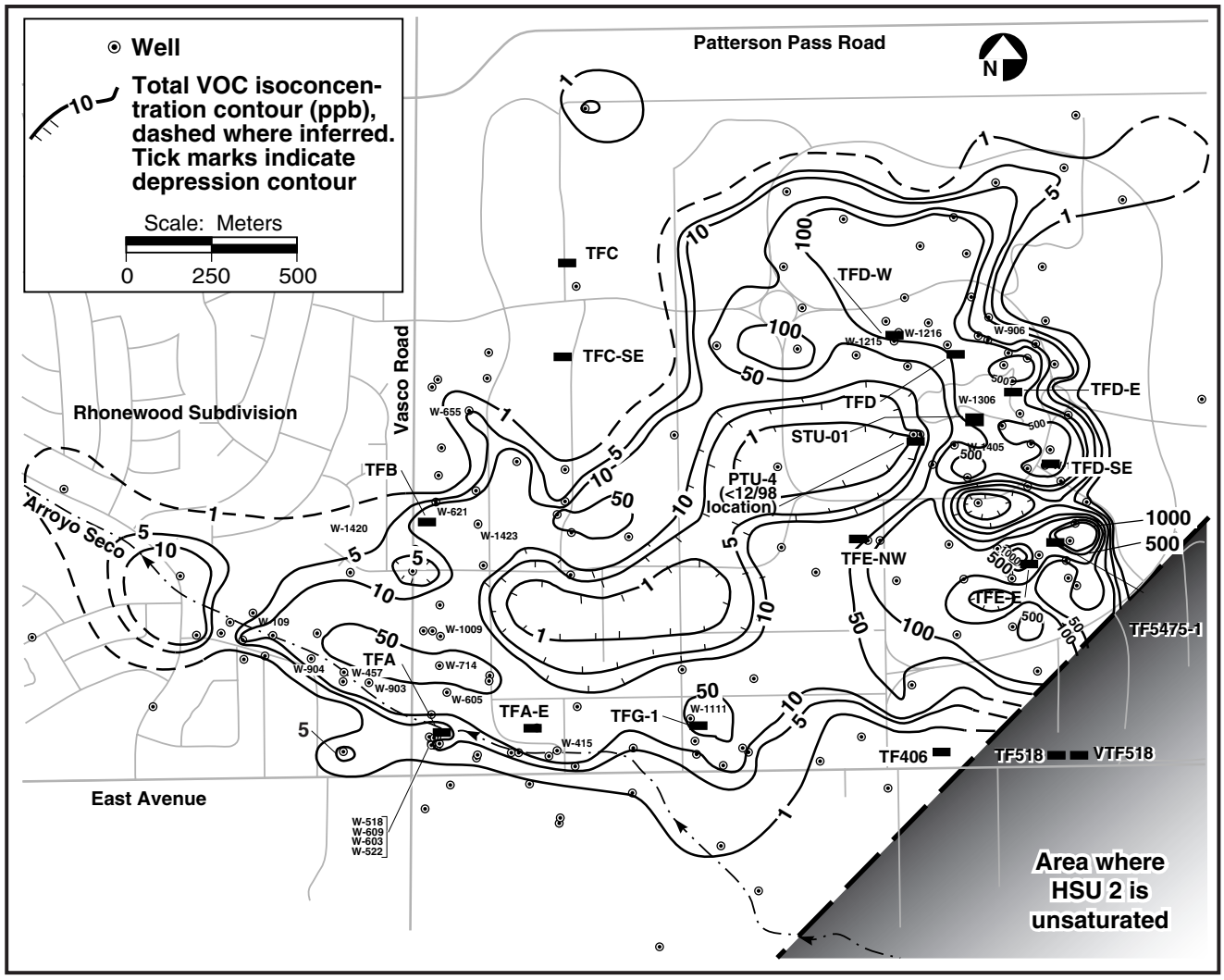


Figure 8-4. Isoconcentration contour map of total VOCs within HSU 2.

Treatment Facility C

Treatment Facility C (TFC) is located in the northwest quadrant of the Livermore site (**Figure 8-1**). Portable Treatment Unit (PTU) location TFC Southeast (TFC-SE), located near the intersection of Avenue A and Sixth Street in the northwest quadrant of the Livermore site, treats ground water from one HSU 1B well (W-1213). The combined TFC facilities operated at an average flow rate of 212 L/min in 1999. TFC and TFC-SE process VOCs in ground water using air stripping. The effluent air from the stripper is treated with granular activated carbon prior to discharge to the atmosphere. Ground water is treated for chromium(VI) in an ion-exchange unit during the winter months, in order to meet the current RWQCB discharge substantive requirements. Wells in the TFC

area pumped at a combined flow rate of about 212 L/min and treated about 93 ML of ground water containing an estimated 9.0 kg of VOCs. Treated ground water from TFC is discharged into Arroyo Las Positas. Treated ground water from TFC-SE is discharged into a north-flowing drainage ditch that empties into Arroyo Las Positas to the north. The TFC effluent chromium(VI) concentration was 32 ppb in February 1999, above the wet season discharge limit of 22 ppb. The ion exchange unit was regenerated and subsequent samples were below the chromium(VI) discharge limit through the end of 1999. TFC–SE was in compliance with all permits throughout 1999. No new wells were installed at TFC during 1999 (**Table 8-3**).

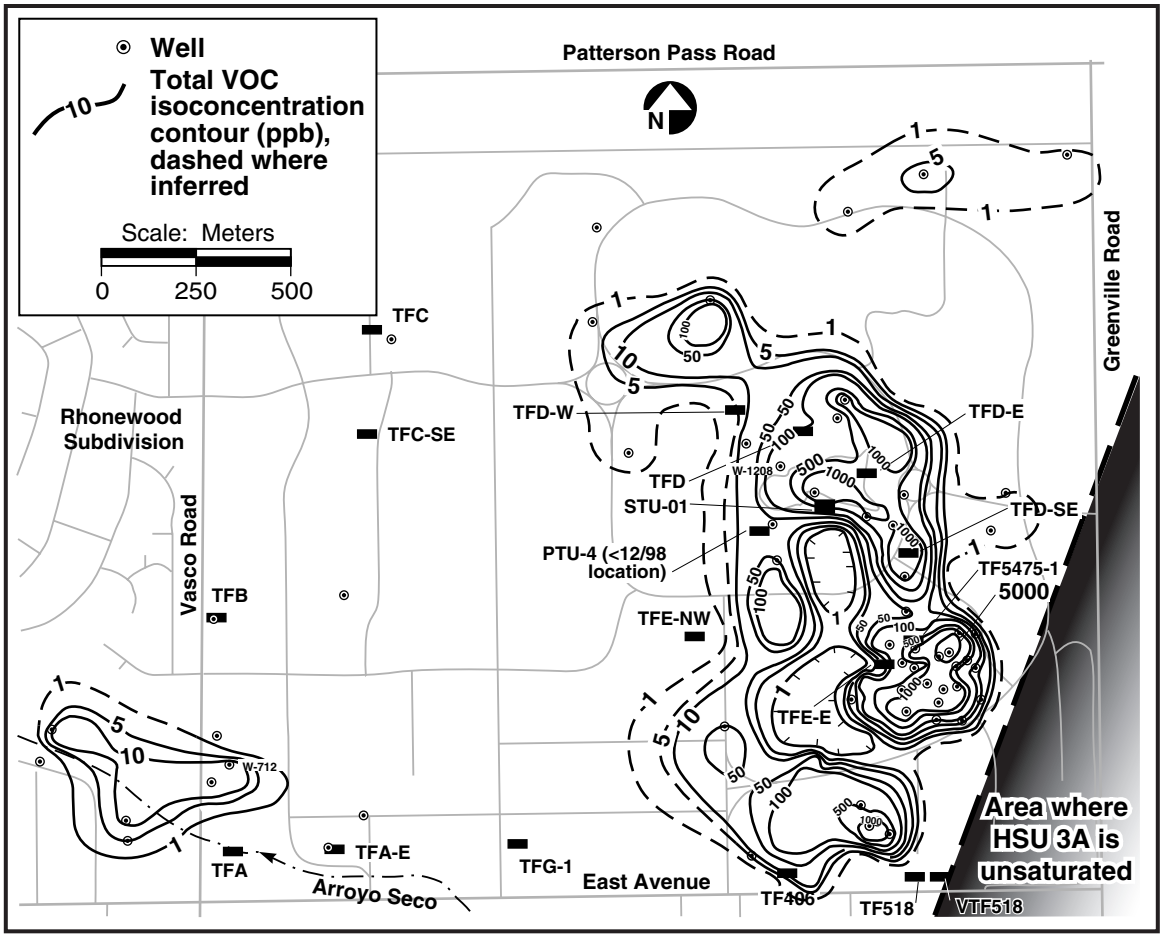


Figure 8-5. Isoconcentration contour map of total VOCs within HSU 3A.

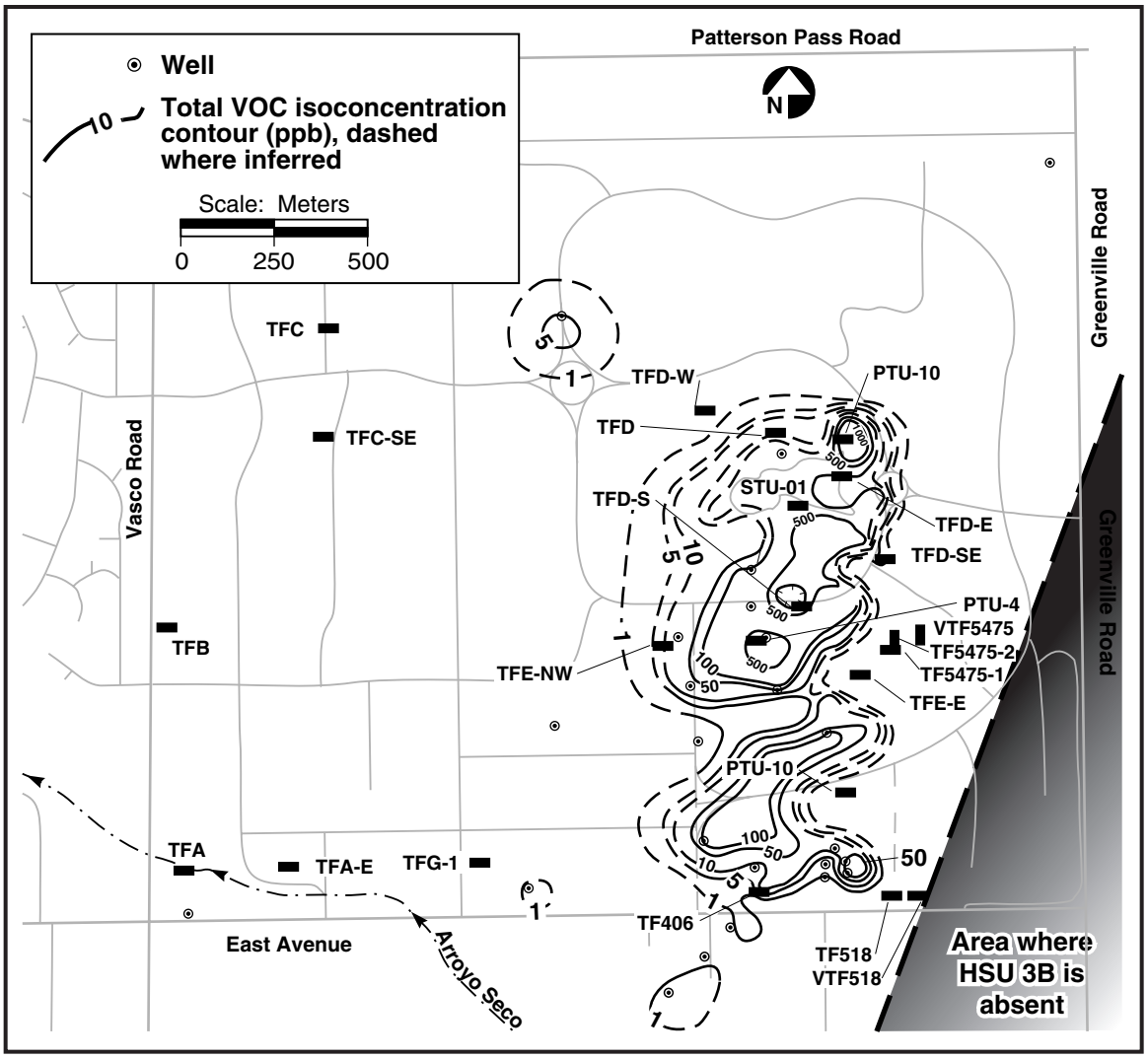


Figure 8-6. Isoconcentration contour map of total VOCs within HSU 3B.

Treatment Facility D

The Treatment Facility D (TFD) area is located in the northeast quadrant of the Livermore site (see **Figure 8-1**). Treatment facilities operating in this area include TFD; portable treatment units (PTUs) operating at TFD-East (TFD-E), TFD-West (TFD-W), TFD-South (TFD-S), TFD-Southeast (TFD-SE); and a solar-treatment unit (STU) operating along the south side of the Drainage Retention Basin (DRB). The combined TFD facilities operated at an average flow rate of 484–590 L/min in 1999. During 1999, these units treated about 226 ML of ground water containing an estimated 88 kg of VOCs. The STU contributed about 1.9 ML of ground water containing an estimated 2.5 kg of VOCs of that total.

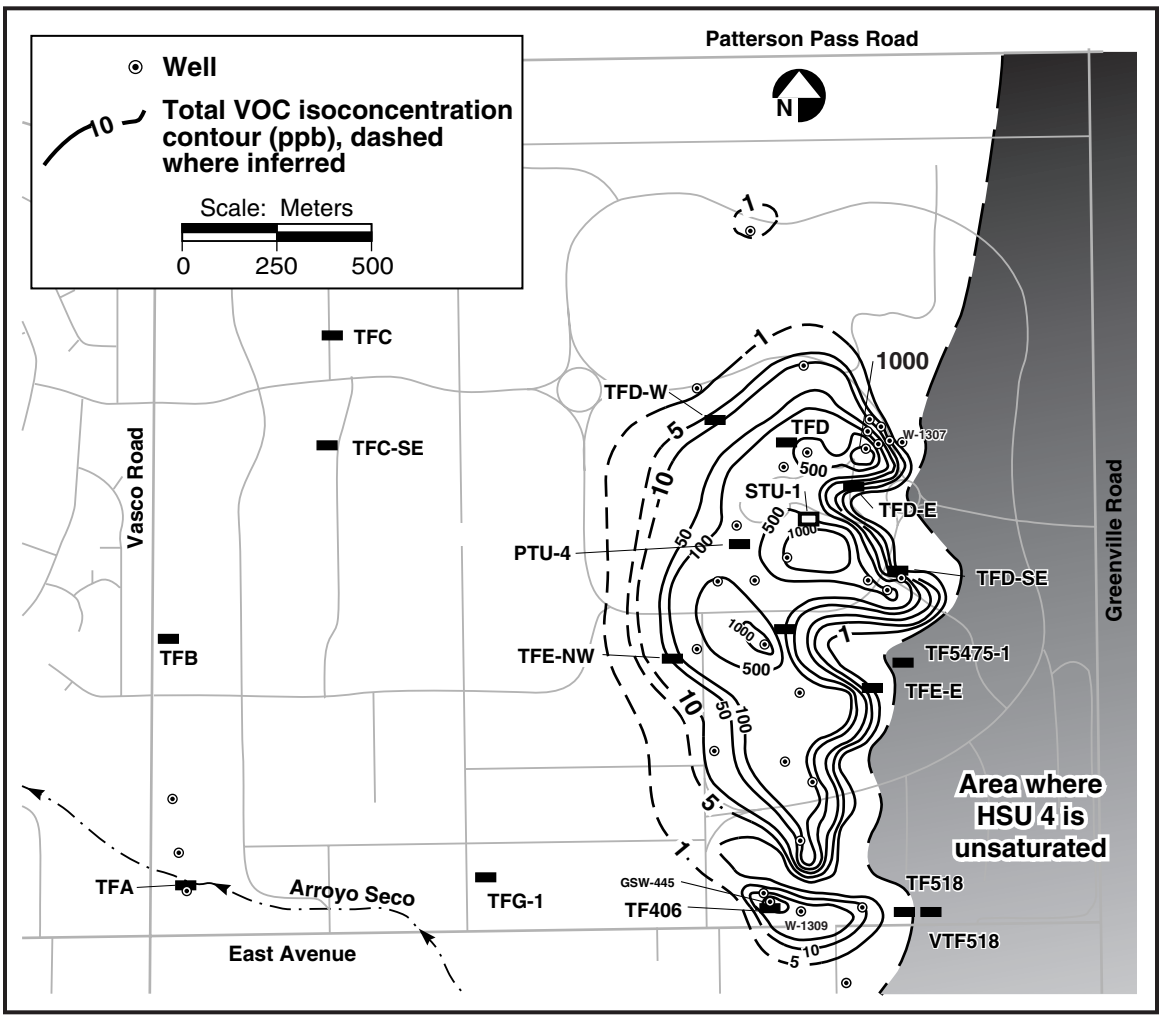


Figure 8-7. Isoconcentration contour map of total VOCs within HSU 4.

Fixed and portable facilities operating in the TFD area process VOCs in ground water using air stripping, although the STU uses granular activated carbon. The effluent air from the air strippers is treated with granular activated carbon prior to discharge to the atmosphere. Treated ground water from TFD and TFD-E is discharged either into the DRB or into an underground pipeline downstream of the DRB weir and flows northward to Arroyo Las Positas. Treated ground water from TFD-W is discharged into a nearby storm sewer that also empties into Arroyo Las Positas. Treated ground water from TFD-S and TFD-SE is discharged into drainage ditches, each flowing north into the DRB. All TFD facilities were in compliance throughout 1999.

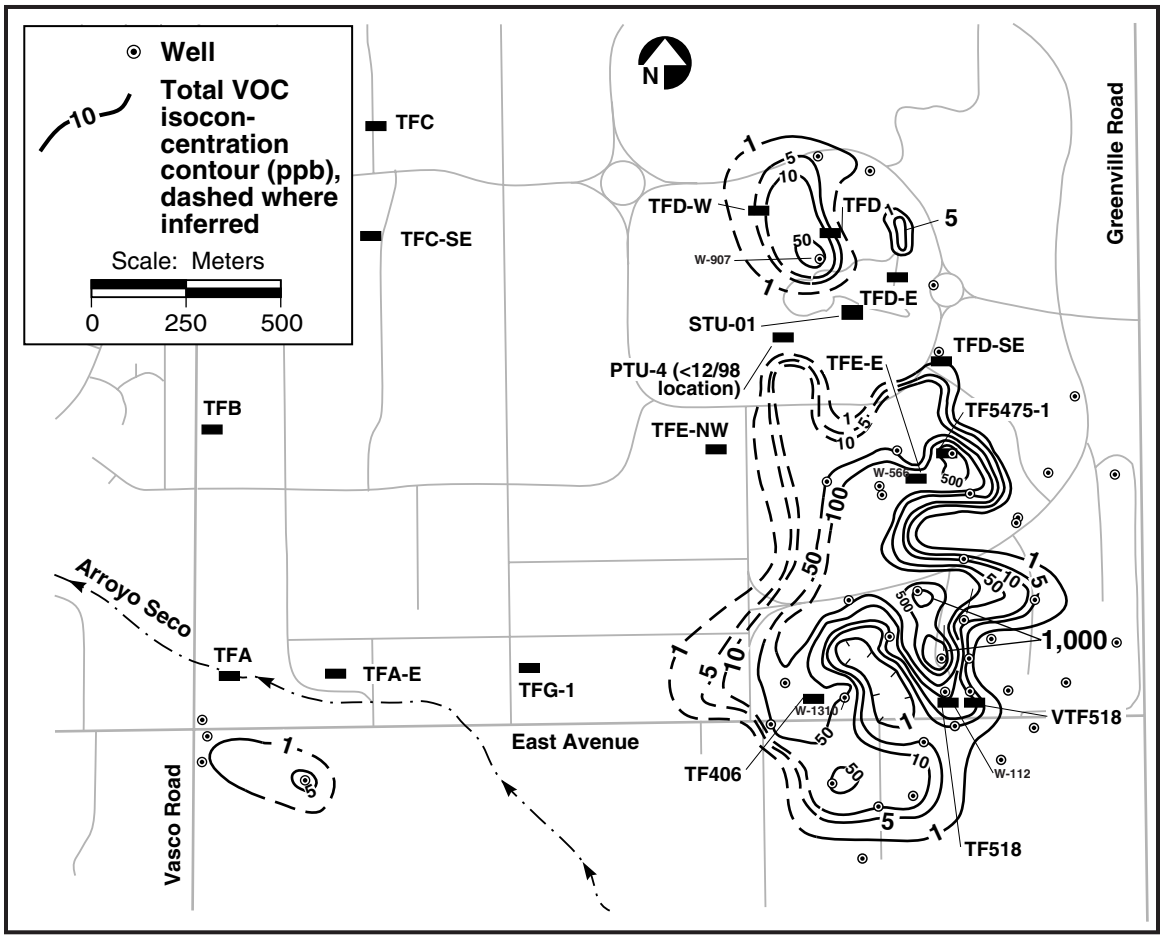


Figure 8-8. Isoconcentration contour map of total VOCs within HSU 5.

The TFD area extraction wells hydraulically control VOCs in HSUs 2, 3A, 3B, 4, and 5. Distal VOC plumes in the western TFD area should be hydraulically controlled once planned TFC-E and TFC-NE treatment facilities are operating, scheduled for June 2002 and May 2003, respectively.

Eleven new monitoring or remediation wells were installed and three new source investigation boreholes were drilled in the TFD area during 1999. Two of those three boreholes were completed as piezometer wells.

In 1999, one-hour drawdown tests were conducted on TFD area wells W-1502, W-1503, W-1504, W-1510, and W-1550 (Aarons 2000).

Table 8-2. 1999 extraction wells and extraction rates.

Treatment facility area	Hydrostratigraphic unit	Extraction wells	Extraction rate (gpm)[a]
TFA	HSU 1B	W-262, W-408, W-520, W-601, W-602, W-1001, W-1004	220–312
	HSU 2	W-109, W-415, W-457, W-518, W-520, W-603, W-605, W-609, W-614, W-714, W-903, W-904, W-1009	
	HSU 3A	W-712	
TFB	HSU 1B	W-610, W-620, W-704	39–81
	HSU 2	W-357, W-621, W-655, W-1423	
TFC	HSU 1B	W-701, W-1015, W-1102, W-1103, W-1104, W-1116, W-1213	54–66
TFD	HSU 2	W-906, W-1215, W-1216, W-1303, W-1306, W-1308, W-1510	128–156
	HSU 3A	W-361, W-1208, W-1301	
	HSU3A/3B	W-1504, W-1551, W-1552	
	HSU 4	W-351, W-1206, W-1307, W-1503, W-314	
	HSU 5	W-907	
TFE	HSU 2	W-1109, W-1409	59–65
	HSU3	W-1422	
	HSU4	W-1211, W-1418	
	HSU 5	W-359, W-566	
TF406	HSU 4	GSW-445, W-1309	9–19
	HSU 5	W-1310	
TFG	HSU 2	W-1111	3.6–8
TF5475	HSU 2	W-1415	1–2.6
	HSU 3A	W-1302	
TF518	HSU 5	W-112	1–5
VTF518		SVI-518-201, SVI-518-303	18 –50 (scfm)[b]
VTF5475		SVI-ETS-504	20 (scfm)
	1999 Total		**514-714 38-70 (scfm)**

[a] gpm = Gallons per minute.

[b] scfm = Standard cubic feet per minute.

Table 8-3. Wells installed in 1999.

Treatment facility area	Hydrostratigraphic unit	Monitoring/extraction wells
TFA	HSU 1B	W-1509, SIP-INF-301, SIP-INF-302
TFB		None
TFC		None
TFD	HSU 2	SIP-ETC-301, SIP-ETC-303, W-1510, W-1512, W-1602
	HSU 3A	W-1603
	HSU 3B	W-1511, W-1601
	HSU 3A/3B	W-1550, W-1551, W-1552, W-1553
	HSU 4	W-1523
TFE	HSU 2	W-1506, W-1517, W-1518, SIP-ETS-601, W-1508
	HSU 3B	W-1522
	HSU 4	W-1505, W-1520
	HSU 5	W-1507, W-1516
TFG		None
TF406	HSU 3A/3B	W-1513, W-1514, W-1515
	HSU 5	W-1519
TF518		None
TF5475	HSU 4	W-1604

In 1999, wells at TFD pumped at a combined flow rate of about 518 L/min and treated about 226 ML of ground water containing an estimated 88 kg of VOCs. An additional PTU operated at wells W-1551 and W-1552 from September to December 1999 in the TFD-E area to expedite VOC mass removal and site cleanup near the TFD source area. Wells W-1551 and W-1552 pumped at a combined flow rate of about 17 L/min, and treated about 2.1 ML of ground water containing an estimated 14 kg of VOCs, which is included in the facility annual total.

Treatment Facility E

The Treatment Facility E (TFE) area is located in the southeastern quadrant of the Livermore site (**Figure 8-1**). In 1999, TFE East (TFE-E) continued treating ground water using a PTU. TFE-E is located in the east-central portion of the Livermore site. TFE-NW treats ground water from extraction wells in HSU 2 and HSU 4 and is located south of the Inner Loop Road, immediately west of Southgate Drive. TFE-E and TFE-NW

process ground water for treatment of VOCs using an air stripper, and the effluent air is treated using granular activated carbon to remove VOCs before it is vented to the atmosphere. Treated ground water from TFE-E is discharged into a drainage ditch that flows north into the DRB. Treated ground water from TFE-NW is discharged into a storm drain that flows north into Arroyo Las Positas. TFE-E and TFE-NW were in compliance throughout 1999.

In the TFE area, the TFE-E extraction wells provide hydraulic containment of some portions of VOC plumes in HSUs 2, 4, and 5. The VOC plumes in HSUs 3A, 4, and 5, located in the western and southern TFE areas, should be hydraulically controlled once the TFE-SW, TFE-SE, and TFE-W treatment facilities are operating. The planned start-up dates for these treatment facilities are June 2000, and January and April 2001, respectively.

In 1999, wells at TFE pumped at a combined flow rate of about 227 L/min and treated about 108 ML of ground water containing an estimated 38 kg of VOCs. An additional PTU operated at wells W-1418 and W-1422 from January to December 1999 in the TFE area to expedite VOC mass removal and site cleanup. Wells W-1418 and W-1422 pumped at a combined flow rate of about 49 L/min and treated about 24.5 ML of ground water containing an estimated 13 kg of VOCs, which is included in the facility annual total.

Ten new wells were installed in the TFE area during 1999. Also, two additional PTUs operated in the TFE area during 1999. PTU-4 continued to operate at wells W-1418 (HSU 4) and W-1422 (HSU 3B) in the northern part of the TFE area to expedite VOC mass removal and site cleanup.

PTU-10 operated at TFE-SE extraction well W-359 (HSU 5) from March to June 1999. During 1999, well W-359 pumped at an average flow rate of about 37 L/min, and PTU-10 treated about 4.9 ML of ground water containing an estimated 2.9 kg of VOCs, which is included in the facility annual total.

Treatment Facility G

Treatment Facility G (TFG) is located in the south-central portion of the Livermore site (**Figure 8-1**). Treatment Facility G-1 (TFG-1) is located near Avenue B, about 90 m north of East Avenue. TFG-1 treats ground water for VOCs and chromium(VI). Under the current RWQCB discharge substantive requirements, water from TFG-1 requires treatment for chromium(VI) only during the winter months. Treated ground water from TFG-1 is discharged to a storm drain located about 50 ft north of TFG-1, which empties into Arroyo Seco. No boreholes or wells were drilled, and no hydraulic tests were conducted in the TFG area during 1999.

Before May 1999, TFG-1 processed ground water for VOC treatment using an air stripper, and the effluent air was treated using GAC to remove VOCs before they were vented to the atmosphere. In May 1999, the PTU at TFG-1 was replaced by a GAC treatment unit (GTU). A year-long treatability study conducted in 1998 and 1999 demonstrated that the GAC treatment was effective in the efficient removal of VOCs from TFG area ground water. Three 400-lb GAC canisters in series are used to process the water from well W-1111 from HSU 2 (**Figure 8-4**). Ground water is no longer treated for chromium(VI) because concentrations from March 1997 through November 1999 had consistently been below the discharge limit of 22 ppb.

TFG-1 was in compliance with all permits from January to October 1999. The TFG-1 effluent chloroform concentrations in November and December were 6.7 and 49 ppb, respectively, exceeding the discharge limit because the GAC filters exceeded their capacity to contain contaminants. The carbon in the unit was replaced and subsequent samples were nondetect for chloroform.

Treatment Facility 406

Treatment Facility 406 (TF406) is located east of Southgate Drive near East Avenue in the south-central part of the Livermore site. TF406 treats ground water to remove VOCs using an air stripper. The effluent air is passed over granular activated carbon to remove VOCs before it is vented to the atmosphere. All treated ground water was discharged to a storm drain that flows to Arroyo Las Positas. TF406 was in compliance throughout 1999.

TF406 processed ground water from extraction wells GSW-445, W-1309, and W-1310.

Passive bioremediation to remediate fuel hydrocarbons continued in the TF406 area during 1999 in HSUs 3A and 3B. Active ground water extraction and treatment for residual dissolved fuel hydrocarbons at Treatment Facility F was discontinued in 1996 with regulatory agency concurrence (San Francisco Bay Regional Water Quality Control Board 1996).

The TF406 extraction wells provide significant hydraulic control of VOC plumes in HSUs 4 and 5 near the TF406 facility. The VOC plumes in HSUs 3A, 4, and 5 should be hydraulically controlled throughout the TF406 area once treatment facilities at TF406-NW and TF518-N are installed in January 2000 and 2002, respectively. Four new wells were drilled and completed at TF406 during 1999 (**Table 8-3**).

During 1999, TF406 operated at an average flow rate of 60 L/min, treating more than 26 ML of ground water containing an estimated 1.0 kg of VOCs (see **Table 8-2**). Since

system startup in 1996, TF406 has treated about 28 ML of ground water and removed about 1.0 kg of VOC mass from the subsurface (see **Table 8-1**).

During 1999, DOE/LLNL began evaluating electro-osmosis for remediating VOCs in fine-grained, low-permeability sediments. The TF406 area was chosen as a test location because prior characterization indicated the presence of good candidate lithologic sequences. Initial testing was conducted to determine design parameters (e.g., electrode spacing, voltage gradients), to evaluate operational issues (e.g., control of high pH and hydrogen gas at the cathode), and to measure electrochemical properties of the soil (e.g., electrical and electro-osmotic conductivity). The results of this work will be used for subsequent analysis and modeling necessary to evaluate electro-osmosis for potential deployment at LLNL. A report summarizing the results of the qualifications phase tests was issued in December 1999 (McNab 1999).

Ground Water Treatment Facility 518

Treatment Facility 518 (TF518) is located in the southeastern quadrant of the Livermore site, north of East Avenue and near Avenue H, adjacent to VTF518 (**Figure 8-1**). TF518 was constructed in 1997 and began operating in January 1998. In 1999, TF518 treated ground water from one extraction well, W-112 (HSU 5).

Sustainable flow rates from well W-112 have decreased steadily during 1999 from about 75 L/min to about 3.8 L/min in May 1999. TF518 periodically shut down during 1999 because of lack of sustainable flow and low water level conditions within well W-112. Hydraulic data indicate that the cumulative pumping from HSU 5 wells at TF406, TFE, and TF518 has significantly lowered ground water levels in the southeastern portion of the Livermore site and reduced yields observed in well W-112.

In July 1998, MTU-1 was activated in the TF518 area, replacing the PTU that had processed ground water there since January 1998. The MTU processes ground water for VOC treatment using an air stripper, and the effluent air is treated using GAC to remove VOCs prior to venting to the atmosphere. All treated ground water is discharged to a storm drain located about 250 ft north of TF518 that empties into Arroyo Las Positas. TF518 was in compliance with all permits throughout 1999.

During 1999, TF518 operated at an average flow rate of 7.6 L/min and treated about 3.6 ML of ground water from well W-112 containing an estimated 0.2 kg of VOCs (see **Table 8-2**). Since the facility started up in January 1998, TF518 has processed more than 14 ML of ground water containing an estimated 1.2 kg of VOCs (see **Table 8-1**). No boreholes or wells were drilled in the TF518 area during 1999. A step-drawdown test was conducted on proposed TF518-N extraction well W-1410.

A two-month recovery test was conducted on HSU 5 wells in the southwestern corner of the Livermore site to evaluate the effects of dewatering by extraction and recharge in this hydrostratigraphic unit. Between July 15 and September 7, 1999, the pumps in all HSU 5 extraction wells at the Livermore Site were shut off, and the rate of ground water recovery was observed in both the extraction wells and in surrounding HSU 5 monitor wells. While the rate of recovery at extraction wells W-1310 (TF406) and W-566 (TFE-E) and adjacent observation wells performed as expected by recovering at a relatively fast rate when pumping ceased, recovery in well W-112 (TF518) and surrounding monitor wells was very slow. The cause for this apparently was a lack of available ground water in the vicinity. The impact of the dewatering on the cleanup of the TF518 area is currently being evaluated.

PTU-10 was operated at proposed TF518-N extraction well W-1410 (HSU 3B) in September 1999. During this period, well W-1410 pumped at an average flow rate of about 44 L/min, and treated about 0.49 ML of ground water containing an estimated 0.1 kg of VOCs. These data are included in the TF518 volume and mass totals, as presented in **Table 8-1**.

Vapor Treatment Facility 518

Vapor Treatment Facility 518 (VTF518) is located in the southeastern quadrant of the Livermore site. Soil vapor is extracted from the vadose zone, and VOCs are removed from the vapor using granular activated carbon canisters. Following treatment, the effluent air is discharged to the atmosphere. VTF518 was in compliance with the Bay Area Air Quality Management District (BAAQMD) permit throughout 1999.

Two instrumented membrane system (IMS) sampling/monitoring wells, SEA-518-301 and SEA-518-304, continue to monitor vadose zone remediation in the VTF518 area. The IMS system is used to collect vapor pressure, soil temperature, soil moisture, and soil vapor concentration data at various discrete depths.

During 1999, VTF518 operated at an average flow rate of 1.4 m^3/min, treating about 101,952 m^3 of vapor containing an estimated 13.1 kg of VOCs (see **Table 8-2**). Since system startup in 1995, VTF518 has treated about 418,258 m^3 of vapor and removed about 147 kg of VOC mass from the subsurface (see **Table 8-1**).

Treatment Facility 5475

The Treatment Facility 5475 (TF5475) area is located in the east-central portion of the Livermore site where tritium and VOCs are present in HSU 3A ground water in concentrations above the MCL. TF5475-1, which was activated in September 1998, uses downhole, in situ catalytic reductive dehalogenation (CRD) to treat VOCs in ground water.

This technology is based upon the reaction of dissolved hydrogen on a palladium-alumina catalyst to form ethane, methane, and chloride. Because of the high CRD reaction rates, water is treated in one pass through the unit, and the treatment unit can be placed in the well casing. This technology treats VOCs in ground water while keeping the tritium in the subsurface.

The CRD unit operates in extraction well W-1302, a dual-screened well in which the unit extracts ground water from the lower screened interval and injects treated ground water containing tritium into the upper screened interval. The required destruction efficiency is 90% or higher. The unit's destruction efficiency at TF5475-1 was 80% in April because of low hydrogen supply. The hydrogen supply cell was replaced and the unit's destruction efficiency improved. TF5475-2 was in compliance throughout 1999. One new well was drilled and completed at TF5475 during 1999 (see **Table 8-3**).

TF5475-2 employs an STU that uses a direct-current- (DC-) powered pump to extract ground water and a series of aqueous-phase GAC canisters for treatment. Treated ground water from TF5475-2 is discharged into a storm sewer that flows north into the DRB, and eventually into Arroyo Las Positas. TF5475-2 was in compliance throughout 1999 although anomalous data were reported in June and July that indicated breakthrough of VOCs from the carbon. Subsequent samples from the same carbon indicated no detectable VOCs. The effluent water was collected into a storage tank until the samples were analyzed and results indicated no detectable VOCs in the effluent.

Vapor Treatment Facility 5475

Vapor Treatment Facility 5475 (VTF5475) is located on the northern side of Trailer T5475 in the east-central portion of the Livermore site, and it treats soil vapor from vadose zone well SVI-ETS-504 (see **Figure 8-1**). VTF5475 began operation on January 21, 1999, ahead of the January 29, 1999, Remedial Action Implementation Plan (RAIP) milestone date.

Soil vapor is extracted from the vadose zone using a vapor extraction system and is processed using GAC. Because of elevated tritium concentrations in the vadose zone, VTF5475 has been designed as a closed-loop system. Following removal of VOCs from the process air stream, the tritiated vapor is reinjected into the subsurface at soil vapor inlet well SVI-ETS-505. Because no effluent vapor from VTF5475 is released to the atmosphere, BAAQMD has granted the facility a letter of exemption for 24-hour operation.

Since system startup in 1999, VTF5475 has operated at an average flow rate of 0.6 m^3/min and treated about 59,472 m^3 of vapor containing an estimated 95 kg of VOCs (see **Table 8-2**).

Two IMS sampling/monitoring wells, SEA-ETS-506 and SEA-ETS-507, are used to monitor vadose zone remediation in the VTF5475 area. The IMS system is used to collect vapor pressure, soil temperature, soil moisture, and soil vapor concentration data from various discrete depths.

Ground Water Flow and Transport Modeling

Ground water flow and transport models are used at the Livermore site to support remediation system design and performance evaluation; to support ongoing subsurface characterization activities; and to improve LLNL's ability to forecast, monitor, and interpret the progress of the ground water remediation program. In 1999, development continued on our three-dimensional ground water model for the Livermore site. The three-dimensional model builds vertical resolution into the two-dimensional model previously developed for the Livermore site (Tompson et al. 1995).

Treatment Facility A and B Model

In 1999, LLNL continued to use the three-dimensional ground water flow and contaminant transport model of HSUs 1B and 2 to evaluate perchloroethene (PCE) and trichloroethene (TCE) transport in the TFA, TFB, TFC, and TFG areas. The development of this model is described in detail in Demir et al. (1997) and Vogele et al. (1996). This model, developed using the CFEST (Coupled Flow, Energy and Solute Transport) computer code (Gupta et al. 1987), was calibrated to measured ground water elevation data collected from Livermore site monitoring wells.

Environmental Impact

Notable results of VOC analyses of ground water received from January through December 1999 are discussed below. **Figures 8-3** through **8-8** are isoconcentration maps for total VOCs underlying the Livermore site and vicinity within HSU 1B, HSU 2, HSU 3A, HSU 3B, HSU 4, and HSU 5, respectively.

The HSU 1B off-site VOC plume contours greater than the MCL of 5 ppb cover an area of approximately 20 acres. This is approximately one-third of its size in 1989 when our first ground water treatment facility began operating. The size of the HSU 2 off-site VOC plume over the MCL shows a reduction of 40 percent since 1989 and currently covers an area of about 62 acres.

During the most recent sampling events, the highest VOC concentration in an HSU 1B off-site well was 15.4 ppb in November 1999 at well W-1425. The highest VOC concentration in an HSU 2 off-site well was 40.4 ppb in well W-903 in October 1999.

Overall, the Livermore site VOC plumes have remained relatively stable with respect to size in 1999, and changes in VOC concentrations are mostly observed in response to active ground water extraction. Concentrations in the HSU 1B, 2, and 3A VOC plumes along the western margin of the Livermore site in the TFA, TFB, and TFC areas continued to decline in response to ground water extraction. VOC concentrations near the source area east of TFA continue to decline. Total VOC concentrations at extraction well W-254 declined from 195 ppb in January 1998 to 125 ppb in October 1999. At TFA, off-site VOC plume contours greater than the MCL of 5 ppb are estimated to cover an area of approximately 7 acres in HSU 1B and 42 acres in HSU 2.

In the TFD area, VOC concentrations in parts of HSU 2 continue to decline in response to pumping the TFD extraction wells. VOC concentrations in HSU 2 extraction well W-906 have decreased from 789 ppb in 1995 to 104 ppb in October 1999. In HSU 2 monitor well W-355, VOC concentrations have decreased from concentrations that were consistently above 1000 ppb prior to pumping at well W-906 to 58 ppb in November 1999.

Prior to pumping in the TFD-E area, high VOC concentrations (in the 5000 to 7000 ppb range) were observed in HSU 3A/3B wells W-1551 and W-1552. After three months of ground water extraction from these two wells, VOC concentrations have remained consistently above 5000 ppb. Well W-1551 has the highest VOC mass removal rate, accounting for 7.7% of the total VOC mass removed from the entire site by ground water extraction.

In the TF518 area, the off-site HSU 5 VOC plume has shown significant decreases in VOC concentrations since pumping started at the TF406 and TF518 facilities in August 1996 and January 1998, respectively. Total VOC concentrations in off-site monitor well W-219 declined from 114 ppb in October 1997 to 3 ppb in October 1999.

In the TFE-SE area, LLNL conducted a pilot long-term pumping test for distal plume capture and VOC mass removal at proposed TFE-SE extraction well W-359 between March and June 1999. VOC concentrations in well W-359 increased from 326 ppb in March to 1395 ppb in October 1999. These data indicate that well W-359 is well positioned to capture VOCs from source areas to the south.

In the TFE-E area, VOC concentrations in well W-1109 decreased from 1744 ppb in January 1998 to 787 ppb in October 1999. Ground water extraction rates from well W-1109 increased from 2.5 to 8.8 gpm in 1999 in response to well redevelopment.

In the TFE-SE area, the initial total VOC concentration in newly installed HSU 2 piezometer SIP-ETS-601 was 1874 ppb. This high concentration confirms the presence of a source area that had been indicated on isoconcentration maps.

Site 300 CERCLA Project

Environmental investigations and cleanup activities at Site 300 began in 1981. Site 300 became a CERCLA/Superfund site in 1991, when it was placed on the National Priorities List (NPL). The CERCLA environmental restoration study areas are shown in **Figure 8-9**. The major contaminants of concern are listed in **Table 8-4**.

Table 8-4. Major contaminants of concern found in soil, rock, and ground water at Site 300.

Study area	Contaminant of concern
General Services Area (GSA)	VOCs (primarily TCE)
Building 834 Complex	VOCs (primarily TCE), organosilicate oil, nitrate
High Explosives Process Area	VOCs (primarily TCE) HE[a] (primarily HMX[b]) Nitrate, perchlorate
East and West Firing Areas (EFA/WFA)	Tritium Depleted uranium VOCs (primarily TCE and Freon-113) Nitrate, perchlorate
Building 854	VOCs (primarily TCE) Nitrate, perchlorate
Pit 6	VOCs (primarily TCE) Tritium, nitrate, perchlorate
Building 832 Canyon	VOCs (primarily TCE) Nitrate, perchlorate

[a] HE = high explosives.

[b] HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

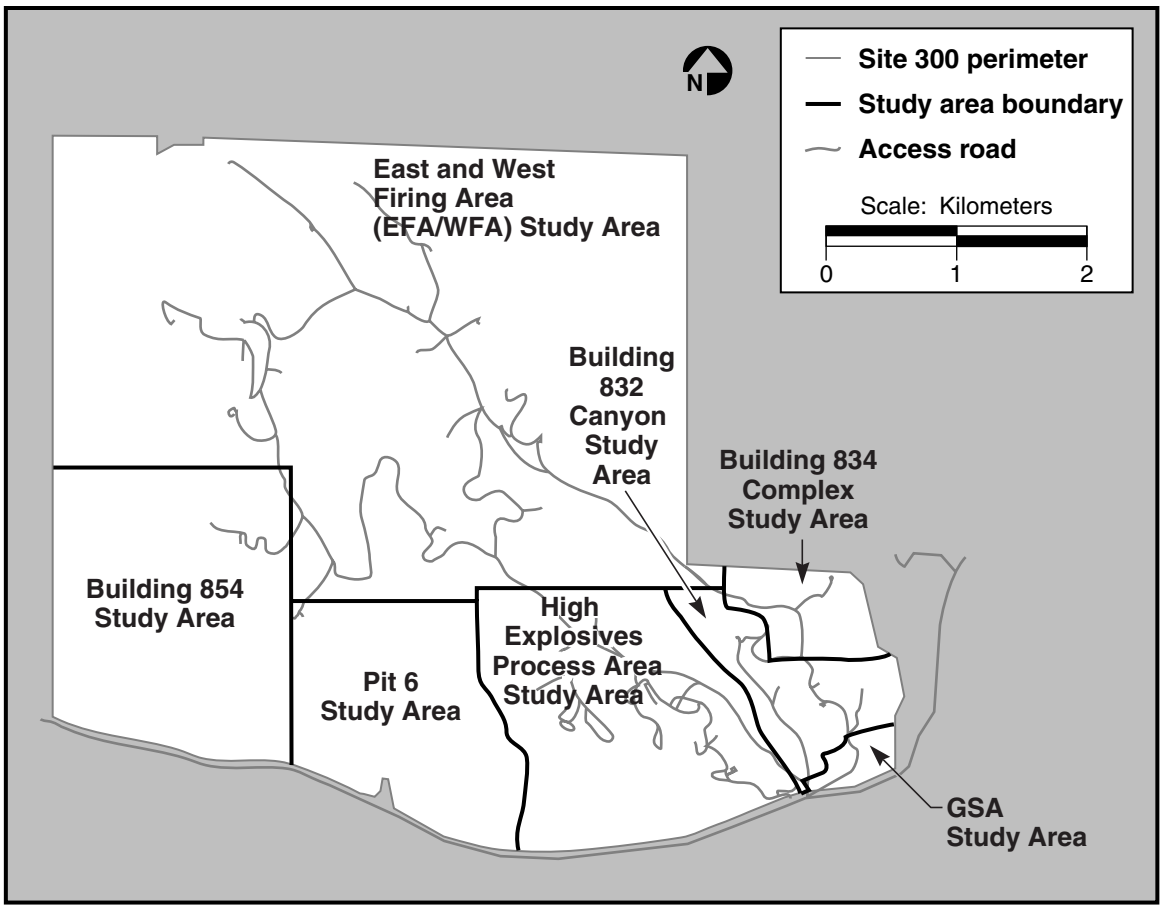


Figure 8-9. Environmental restoration study areas at Site 300.

Geology of Site 300

Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. Site 300 stratigraphy is shown in **Figure 8-10**. Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—alluvium and semilithified sediments, mainly of continental origin.
- Early to late Tertiary (5–65 million years ago)—shallow marine and continental sedimentary and volcaniclastic rocks.

- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimentary rocks and ophiolites) and Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks).

Distinctive blue-gray to brown weathering volcaniclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath the southeastern portion of Site 300.

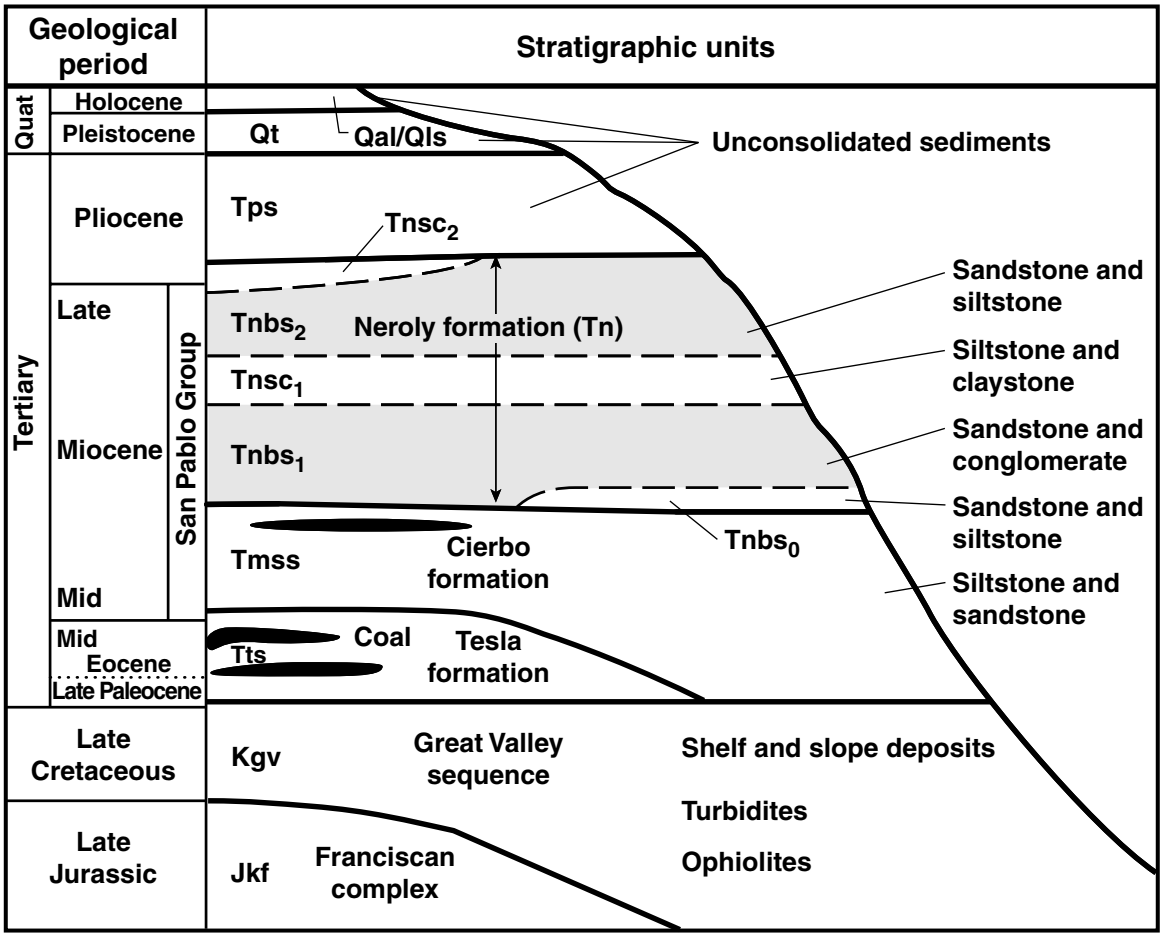


Figure 8-10. Site 300 stratigraphy (Webster-Scholten 1994).

The Neroly Formation is the principal hydrologic unit within Site 300 and has therefore been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300,* hereafter referred to as the Final SWRI Report [Webster-Scholten 1994]). The complete section of the Neroly Formation is about 150 m thick beneath Site 300.

The floodplain of Corral Hollow Creek lies along the southern boundary of Site 300 and borders portions of the General Services Area (GSA), the High Explosives Process Area, and the area of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble and boulder-bearing terrace gravel derived from sources to the south, with lenses and local cappings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, locally influence ground water flow within the site and have therefore been studied in great detail as part of the CERCLA investigations.

Hydrogeology of Site 300

Site 300 is semiarid, with an average annual rainfall of 27 cm (10.5 in). The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock comprises interbedded conglomerates, sandstones, siltstones, and claystones (see **Figure 8-10**).

Ground water primarily occurs in the Neroly Formation upper and lower blue sandstone units ($Tnbs_2$ and $Tnbs_1$) and in the underlying Cierbo Formation (Tmss). Ground water can also be present in permeable Quaternary alluvium valley fill (Qal) during the winter rainy season. Some ground water is present as perched water-bearing zones beneath hilltops. The perched water-bearing zones primarily occur in the unconsolidated sediments of the Miocene-age nonmarine unit (Tps) in the Building 833 and 834 areas and in the Explosives Process Area. However, an extensive perched water-bearing zone occurs in $Tnbs_1$ sandstones in the northwestern portion of the East and West Firing Area. Fine-grained siltstone and claystone interbeds in $Tnbs_1$ and Tmss act as aquitards, confining layers, or perching horizons. Portions of the bedrock section at Site 300 are abundantly fractured, and thus much of the ground water flow occurs in fractures as well as in pores. Ground water is present under confined conditions in the southern half of the site but is generally unconfined elsewhere. **Figure 8-11** is a map of the potentiometric surface for the first continuous water-bearing zone at Site 300, which principally occurs in the Neroly lower blue sandstone aquifer ($Tnbs_1$).

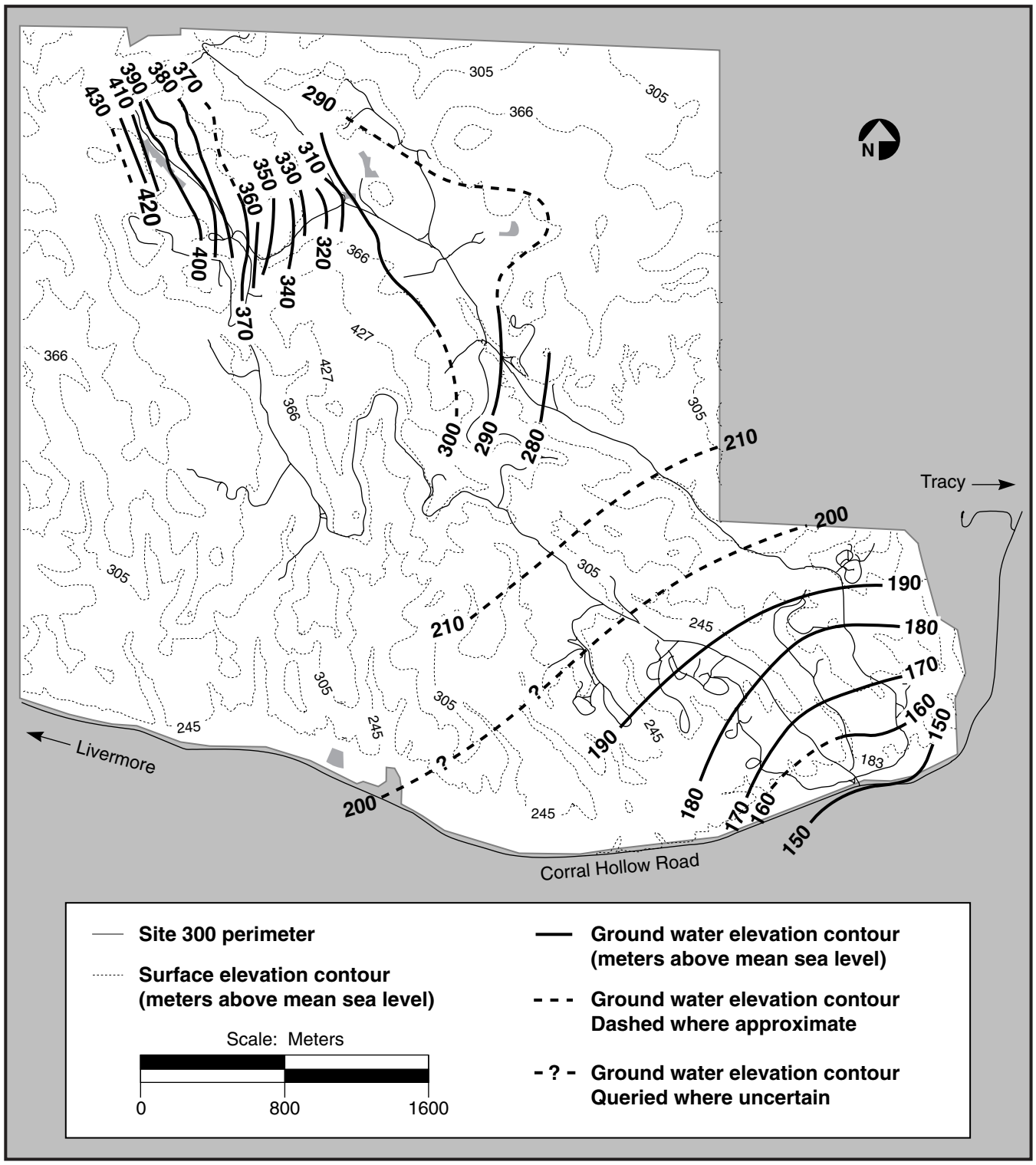


Figure 8-11. Approximate ground water elevations in the principal continuous water-bearing zone at Site 300.

Recharge occurs where saturated alluvial valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out. Local recharge occurs on hilltops, creating the perched water-bearing zones in the Building 832, 834, and 854 areas. Low rainfall, high evapotranspiration rates, steep topography, and intervening aquitards generally preclude direct vertical recharge to the deeper bedrock aquifers.

Ground water flow in the bedrock follows the inclination, or dip, of the layers. The tectonic forces that uplifted the Altamont Hills faulted, gently folded, and tilted the once-horizontal sedimentary strata. A major structure, the east-west trending Patterson anticline, occupies a central location within the site. North of the anticline, bedrock dips east-southeast, and ground water flows generally east-northeast. South of the anticline, bedrock dips south-southeast, and thus ground water flows roughly south-southeast.

The Cierbo Formation (Tmss) is saturated beneath Doall Ravine, the Building 851 and 854 areas, and the southern part of the East Firing Area. The Tmss unit is unsaturated or does not otherwise yield water to wells in other parts of the East and West Firing Areas. The thickness of the Cierbo Formation is not well known because most boreholes are not deep enough to completely penetrate this formation. Some of the deeper wells in the GSA penetrate the uppermost Tmss. The continuity of saturation in the Tmss between the northwest and southeast areas of Site 300 is undetermined. Ground water in the Tmss occurs under unconfined to artesian conditions.

The Tps unit is the youngest bedrock unit identified at Site 300 and is generally present only on hilltops. Where present, ground water is typically perched, discontinuous, and ephemeral. The exception to this condition exists in the Explosives Process Area, where the extent of saturation in Tps sediments is significant. Ground water in the Tps unit is generally unconfined, although water under confined conditions does occur locally.

Quaternary alluvium (Qal) is present as valley fill in ravines throughout Site 300, but is saturated only in the Corral Hollow Creek stream channel, in Doall Ravine in the West Firing Area, and in southern Elk Ravine in the East Firing Area near a spring. Saturated Quaternary terrace alluvium deposits (Qt) are present at Pit 6, in the GSA, and in the Building 832 Canyon area; some of these ground water occurrences are ephemeral. Small quantities of ground water are present in some local landslide (Qls) deposits.

All ground water contaminant plumes at Site 300 occur in Neroly Formation (Tn) rocks, unamed Pliocene nonmarine sediments (Tps), or unconsolidated Quaternary sediments (Qal , Qls, or Qt) stratigraphic units. The extent of ground water contamination at Site 300 is shown on **Figure 8-12**.

Study Area Highlights and Activities

Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994). In 1999, LLNL submitted the *Draft Final* and *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 1999c) and the *Draft Final Proposed Plan for Environmental Cleanup at Lawrence Livermore National Laboratory Site 300* (Dresen et al. 1999).

Background and activities for each of the study areas are described in the following sections. Ground water remediation for Site 300 is discussed in more detail later in this chapter. See Chapter 9 for a discussion of 1999 ground water monitoring.

General Services Area

In the General Services Area (GSA), past leaks of solvents from storage areas and other facilities have resulted in several plumes of VOCs in ground water. Two ground water TCE plumes and two corresponding treatment facilities are present at both the eastern and central GSA. The VOC ground water plume in the eastern GSA is present in stream channel alluvium (Qal) at 3–9 m below ground surface; the plume, as defined by the detection limit, is about 183 m long (**Figure 8-13**). Ground water in the alluvium flows down Corral Hollow Creek, east and northeast. Maximum fourth quarter 1999 total VOC ground water concentrations from eastern GSA monitoring wells were 10 ppb. The Qal is hydraulically connected to the Neroly Formation lower blue sandstone ($Tnbs_1$) unit.

The two VOC ground water plumes in the central GSA are present in terrace alluvium (Qt) and Neroly Formation upper blue sandstone ($Tnbs_2$), at a depth of 3–9 m below ground surface. These VOC plumes are about 170 m and 350 m long (**Figure 8-14**). Maximum fourth quarter 1999 total VOC alluvial ground water concentrations were 1100 ppb. Deeper regional ground water also contains total VOCs at a maximum fourth quarter 1999 concentration of 20 ppb. This ground water occurs at depths of 11–56 m below ground surface.

Details of current and planned environmental restoration activities at the GSA are summarized in the *Final Remedial Design* document (Rueth et al. 1998). The remedial design document includes the Contingency Plan and Compliance Monitoring Plan for the GSA operable unit (OU).

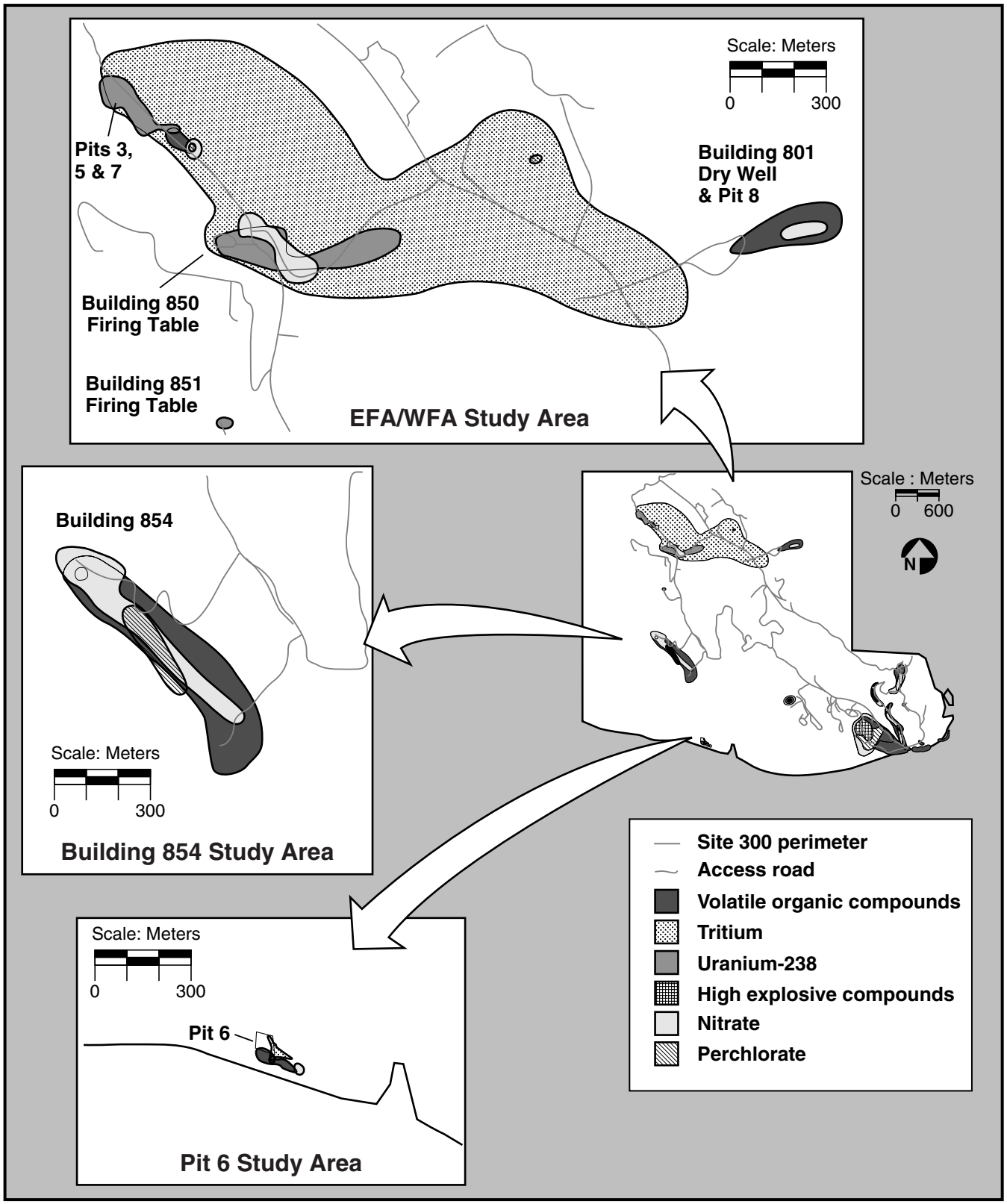
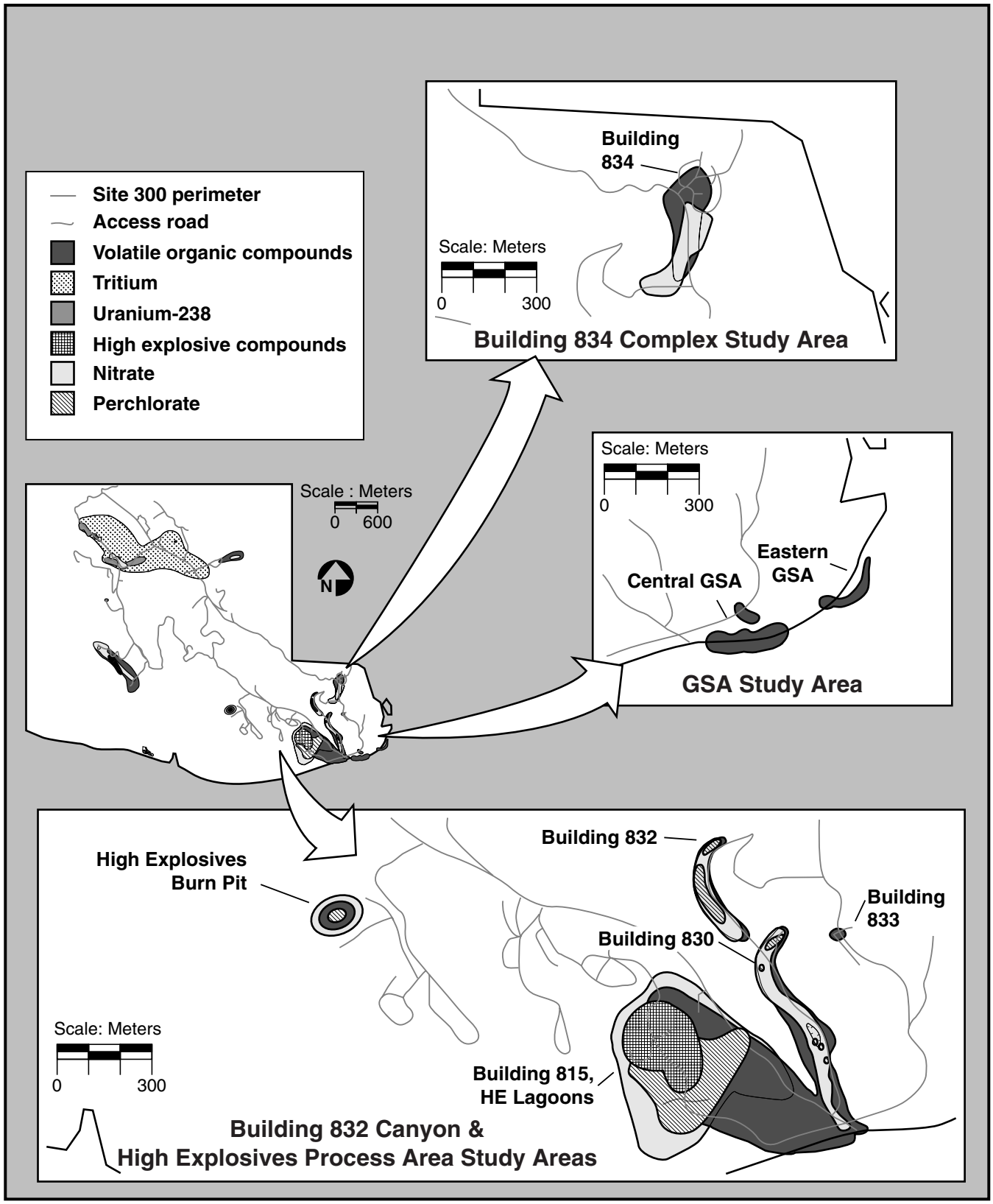


Figure 8-12. Extent of ground water contamination at Site 300.


Site 300 perimeter
Access road
Volatile organic compounds
Tritium
Uranium-238
High explosive compounds
Nitrate
Perchlorate
Building 834
Scale: Meters
0 300
Building 834 Complex Study Area
Scale : Meters
0 600
N
Scale: Meters
0 300
Eastern GSA
Central GSA
GSA Study Area
High Explosives Burn Pit
Building 832
Building 833
Building 830
Building 815, HE Lagoons
Scale: Meters
0 300
Building 832 Canyon & High Explosives Process Area Study Areas

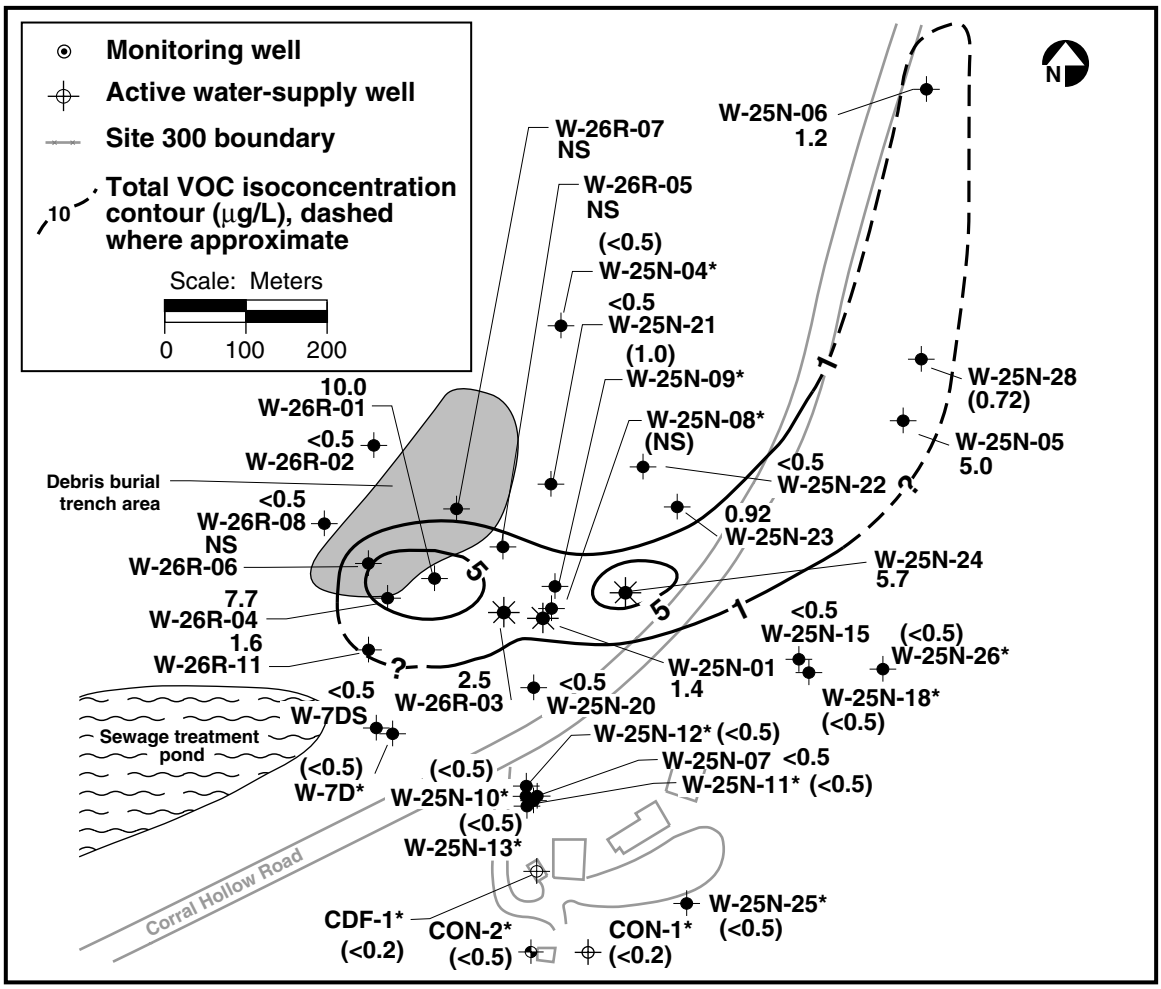


Figure 8-13. Total VOC concentrations in ground water in the eastern GSA and vicinity (fourth quarter, 1999). Monitor wells are completed in alluvial/shallow bedrock aquifer.

Using the results from several hydraulic tests, LLNL determined that the direction of plume migration may follow a previously unknown, now subterranean, river bed. It was observed in the fall of 1999 that the eastern GSA off-site plume (as defined by the >5 ppb TCE contour line) has been restricted to the Site 300 property. It had previously extended more than a mile down the Corral Hollow stream channel toward the City of Tracy, before the treatment facility started up in 1991. We estimate that, through the continued efforts of source elimination and hydraulic containment, LLNL will be able to close the eastern GSA within a few years.

After determining that the eastern GSA VOC plume was restricted to the site, LLNL reconsidered the need for an off-site treatment facility as originally planned for

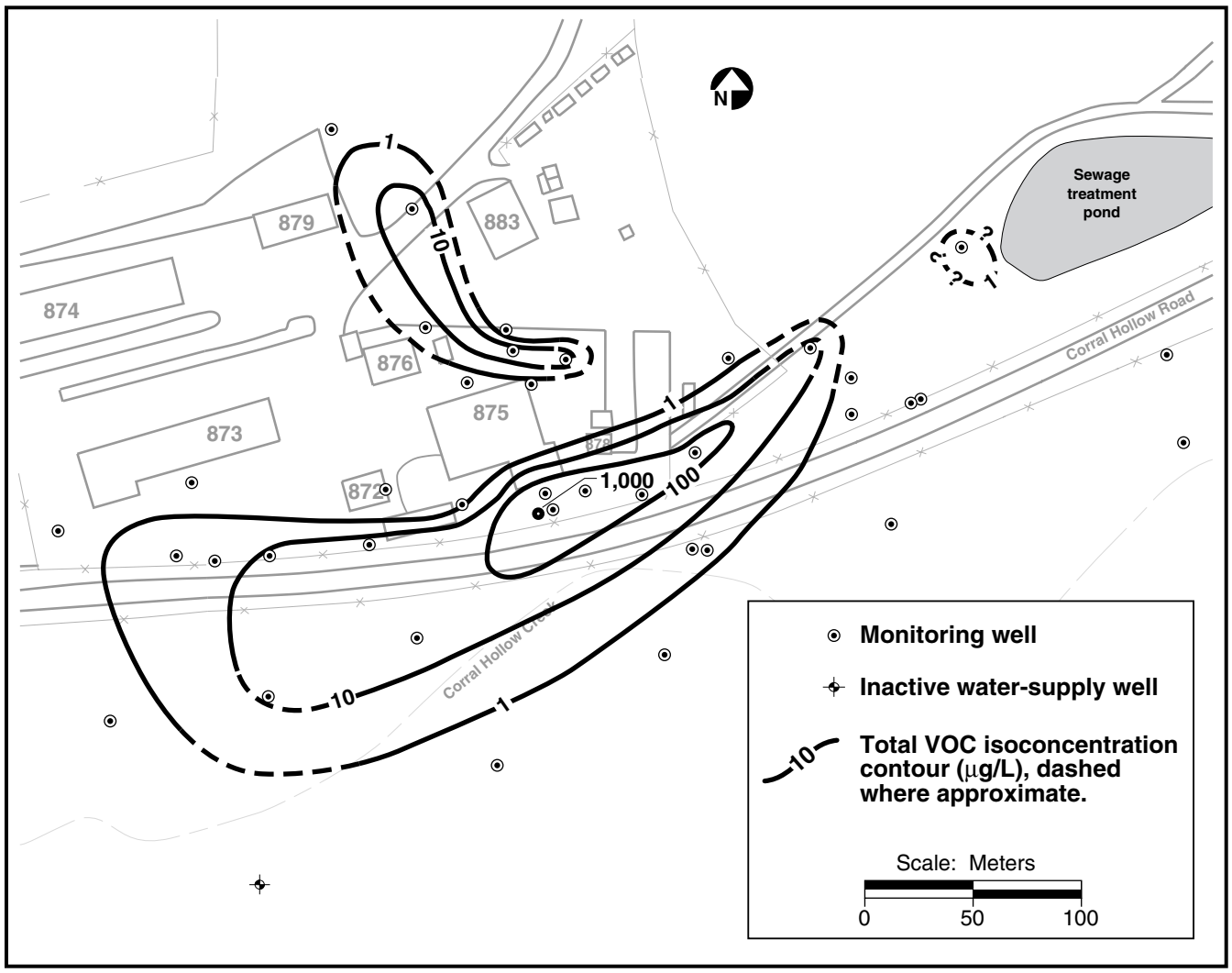


Figure 8-14. Total VOC concentrations in ground water in the central GSA (fourth quarter, 1999). Question marks indicate that the contour is unknown. Monitoring wells are completed in the Qt-Tnsc$_1$ hydrologic unit.

in the Record of Decision, or ROD. Chemical data indicate that trichloroethylene (TCE) concentrations have decreased to below drinking water standards in ground water from all off-site wells. Based on this information, LLNL has determined that an off-site extraction and treatment system is not needed or justified. The regulatory agencies have concurred that the off-site treatment system milestone could be delayed and the need would be re-evaluated during the GSA Five-Year Review.

Building 834 Area

The Building 834 facility contains buildings where, in the past, TCE was used as a heat transfer fluid. Several large spills of TCE to the ground resulted in TCE contamination of a shallow perched water-bearing zone beneath the site. An isolated, discontinuous, perched water-bearing zone occurs in Pliocene non-marine gravels (Tps) and occurs at a maximum depth of 9 m (30 ft) below the center of the complex. This perched zone crops out on all sides of the hill housing the Building 834 complex and is isolated from the underlying regional aquifer by more than 90 m of vadose zone. The water-bearing zone contains maximum 1999 concentrations of TCE and 1,2-DCE of about 94,000 and 110,000 ppb, respectively. The resulting VOC plume is about 600 m long (**Figure 8-15**). Maximum ground water nitrate concentrations are about 205 ppm. A silicate oil (tert-butyl orthosilicate) has been detected at maximum 1999 concentrations of 770,000 ppb. Site characterization was enhanced by surveying the Building 834 area using passive soil vapor monitoring tools (Halden et al. 2000). Currently, ground water and soil vapor extraction and treatment, using air-sparging and GAC, respectively, are in progress.

High Explosives Process Area

The High Explosives Process Area was established in the 1950s to chemically formulate, mechanically press, and machine high explosives (HE) compounds into detonation devices that are tested in explosives experiments in the East and West Firing Areas of Site 300. Process waste water from HE machining operations containing HMX, RDX, and nitrate was discharged to nine former unlined lagoons at concentrations high enough to impact ground water. A TCE hardstand located near the former Building 815 steam plant is considered to be the primary source of TCE ground water contamination. HMX and RDX are the most frequent and widespread HE compounds detected in soil and ground water. TCE, nitrate, perchlorate, and RDX occur in two water-bearing zones within the HE Process Area. These two water-bearing zones occur in Tps sediments and $Tnbs_2$ sandstone, respectively. Ground water occurs in these two zones at depths of 2–30 m, and 20–76 m, respectively. The VOC (principally TCE) plumes in Tps strata are about 300 m and 200 m long. The TCE plume in $Tnbs_2$ strata is about 900 m long (**Figure 8-16**). The RDX plume is about 900 m long. The nitrate plume in $Tnbs_2$ strata is about 900 m long. The perchlorate plume in $Tnbs_2$ strata is 1500 m long. Current 1999 maximum concentrations of TCE, RDX, nitrate, and perchlorate are 160, 100, 102, and 33 ppb, respectively. In 1999, a treatment facility (B815-TF1) was installed near the Site 300 boundary to prevent off-site migration of VOCs in ground water. A small plume of TCE (maximum 1999 concentration of 310 ppb) also occurs in a local perched water-bearing zone that occurs in $Tnsc_1$ strata at a depth of 24–30 m below the HE burn pits; this plume is less than 5 m long. These burn pits were closed and capped under RCRA in 1998.

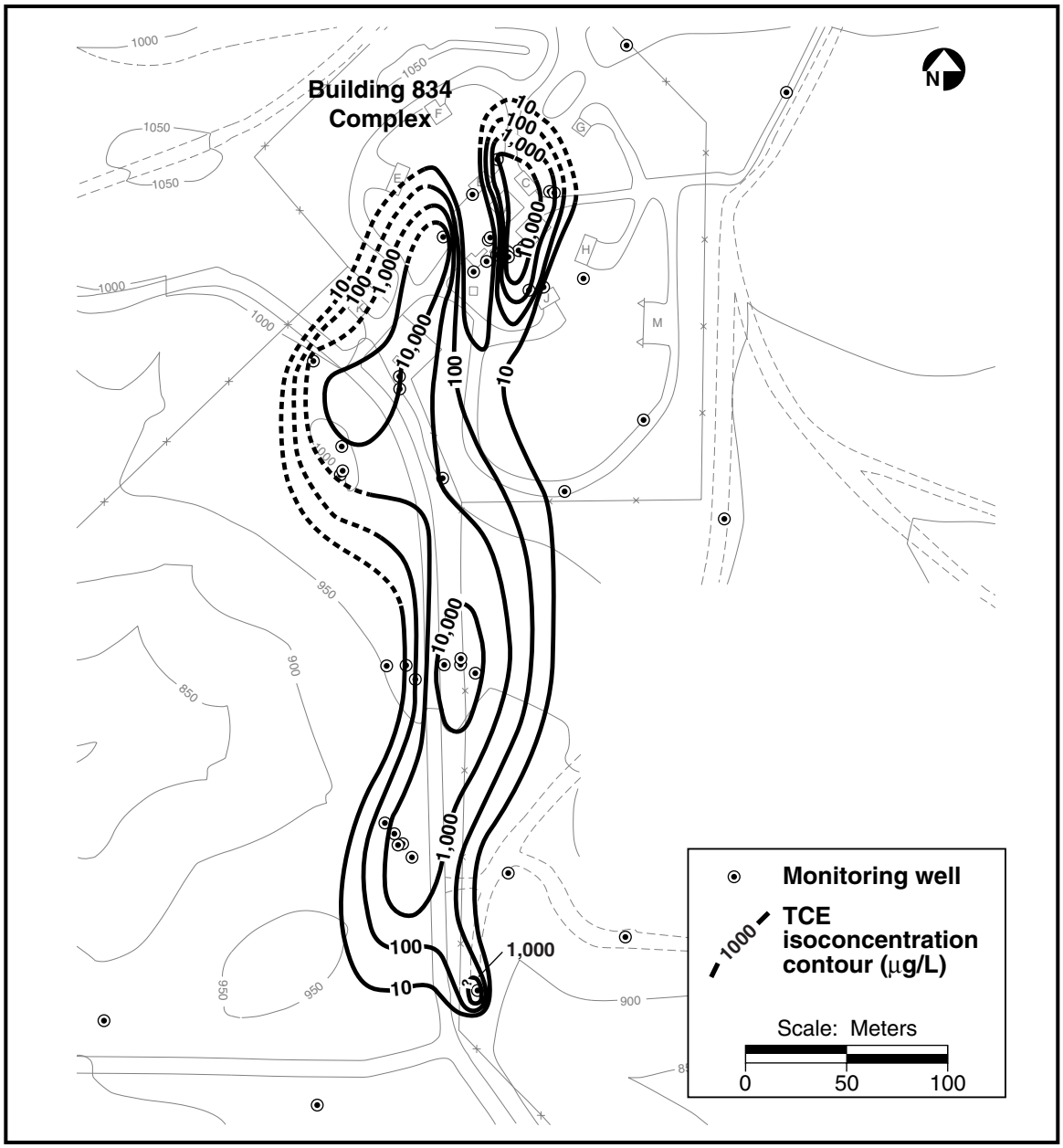


Figure 8-15. Distribution of total VOCs in ground water in the Qt-Tpsg hydrologic unit at the Building 834 complex (second quarter, 1999).

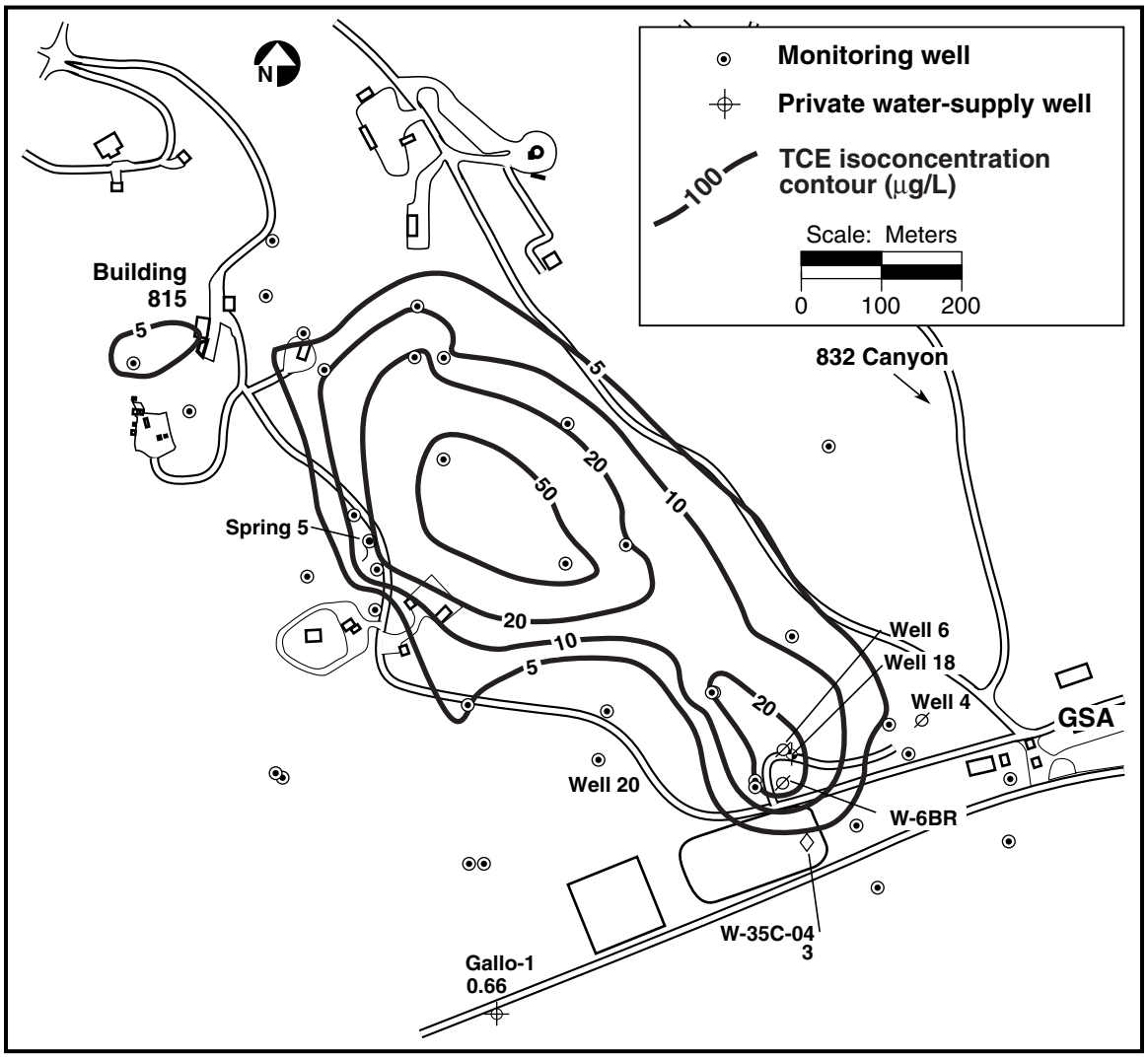


Figure 8-16. Trichloroethene (TCE) isoconcentration contour map in the $Tnbs_2$ aquifer in the HE Process Area (fourth quarter, 1999).

East and West Firing Areas

Explosives experiments conducted at outdoor firing tables in this area have generated wastes that in the past were disposed at several unlined landfills. Tritium has been released to ground water from landfill Pits 3 and 5 and the Building 850 firing table (**Figure 8-17**). Depleted uranium has been released to ground water from landfill Pits 5 and 7 and the Building 850 firing table. The resulting plumes occur in a perched water-bearing zone within Qal and $Tnbs_1$. The water-bearing zone occurs at depths of 5–20 m below surface. There are two overlapping plumes of tritium in ground water.

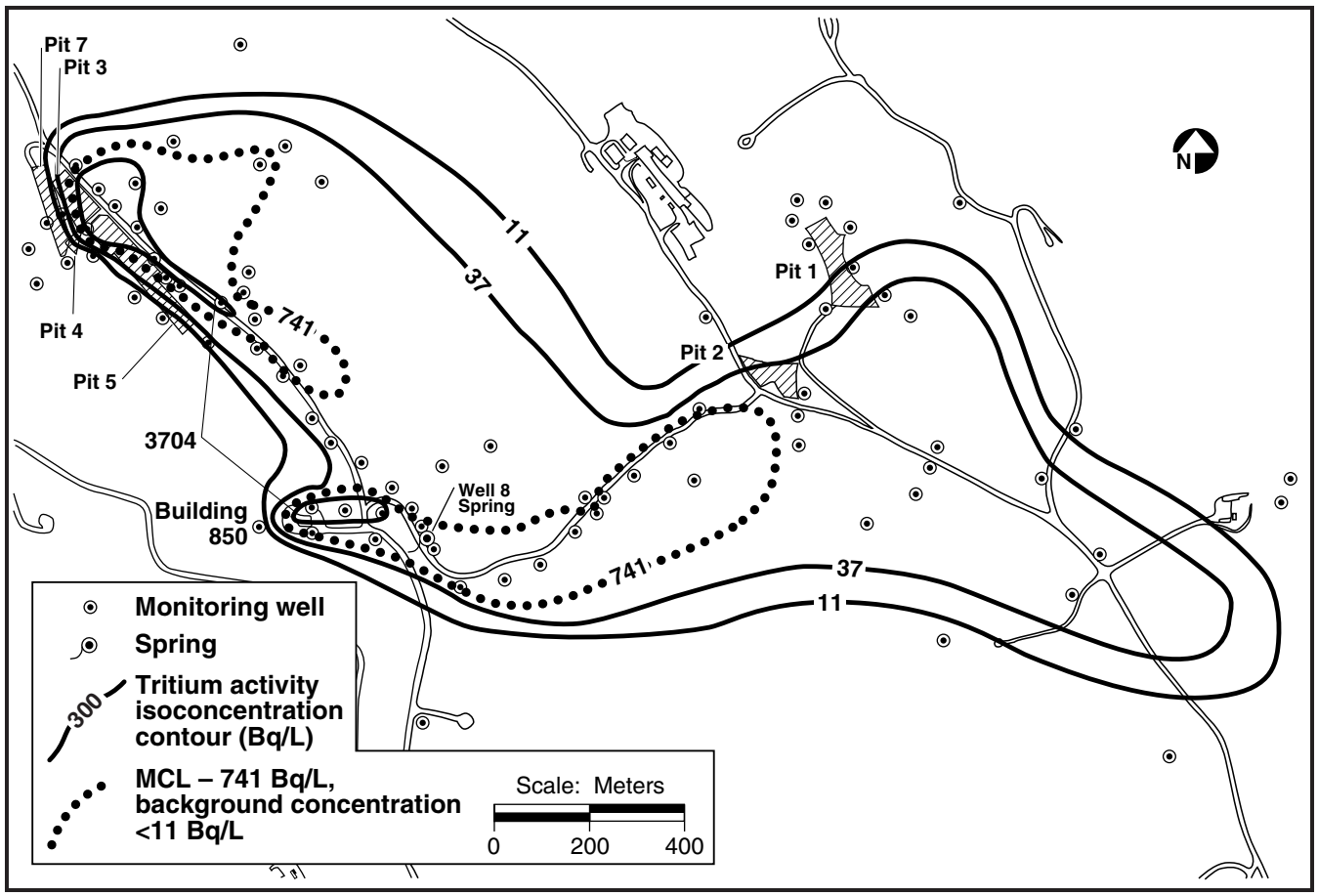


Figure 8-17. Distribution of tritium in ground water in the first water-bearing zone in the Building 850/Pits 3 and 5 area (second quarter, 1999).

The maximum 1999 tritium activity is about 36,963 Bq/L (999,000 pCi/L). The total length of the commingling tritium plumes is about 3000 m. The perched water-bearing zone is connected to the regional $Tnbs_1$ aquifer at the Elk Ravine Fault. Maximum 1999 ground water tritium activities in this aquifer are about 703 Bq/L (19,000 pCi/L). There are two smaller plumes of depleted uranium (uranium-238) in ground water, with maximum 1999 activities of less than 3.7 Bq/L (100 pCi/L). The depleted uranium is confined to the perched water-bearing zone; the lengths of these two uranium plumes are 370 m and 500 m. Computer modeling of the transport and fate of the tritium indicates that by the time the tritium and uranium in ground water reach the Site 300 boundary, these radionuclides will exist at near-background activity levels.

During 1999, LLNL installed a total of 15 new monitor wells in the East and West Firing Area. Ten of these wells were drilled to define the extent of tritium in ground water and the effects of the Elk Ravine Fault on ground water flow in the area northeast of the

valley that houses landfill Pits 3, 5, and 7. Ground water tritium activity data from these wells indicate that the tritium plume emanating from the pits is somewhat more extensive than previously thought. The plume is now bounded by wells that sample ground water that contains background tritium activities. The other five wells were completed to monitor alluvial ground water in the landfill valley.

To determine the appropriate remediation strategy for the landfills, LLNL is currently conducting an evaluation of tritium sources within the landfills and is building a three-dimensional structural model and a finite element model of ground water flow and contaminant transport. To this end, during 1999, LLNL analyzed 68 samples from 16 boreholes for tritium activity and water content. The highest activity found was 255,300 Bq/L_{sm} (6.9 MpCi/L_{sm}) in a sample of waste from Pit 3.

Although tritium continues to leach into ground water from vadose zone sources at Building 850, the long-term trend in total ground water tritium activity in this portion of the tritium plume is one of decreasing activity at approximately the radioactive decay rate of tritium. The extent of the 740 Bq/L (20,000 pCi/L) MCL contour for this portion of the plume is shrinking.

During 1999, LLNL began its characterization of Freon-113 at Building 865 (the closed Advanced Testing Accelerator). Freon-113 was used as a degreasing agent at the facility. The Freon-113 was originally discovered in ground water samples from wells in the Pit 1 monitoring network, downgradient and southeast of Building 865. During 1999, LLNL completed two wells northeast of Building 865. Maximum Freon-113 concentrations in ground water in this area are significantly less than the 1.2 ppm MCL for Freon-113.

During 1999, LLNL began geological reconnaissance at the Building 812 firing table area. No monitor wells have yet been drilled at Building 812, a firing table where depleted uranium and thorium were used in explosives experiments. However, samples from an adjacent perennial spring indicate depleted uranium signatures. Well drilling will begin at the Building 812 area in 2000.

Several other contaminants in ground water are being investigated by LLNL at the East and West Firing Areas. Nitrate and perchlorate in the Building 850/Pits 3 and 5 areas occur at maximum 1999 concentrations of less than 110 ppm and 5 ppb, respectively. Trace amounts of TCE (less than 3 ppb) are also present in ground water near Pit 5. TCE also occurs in a small ground water plume monitored by two wells at the Building 801 firing table.

Depleted uranium isotopic signatures have been detected in ground water samples from wells adjacent to the Building 851 firing table, indicating that some depleted uranium is reaching ground water.

Building 854 Study Area

Trichloroethene in ground water was previously found to arise principally from leaks in the former overhead TCE brine system at Buildings 854E and 854F. Trichloroethene, nitrate, and perchlorate occur in ground water in the Building 854 area in Neroly Formation $Tnbs_1$ strata at maximum 1999 concentrations of 270 ppb, 200 ppm, and 16 ppb, respectively. The affected aquifer occurs at depths of 9–50 m below ground surface. The TCE plume is about 970 m long (**Figure 8-18**).

During 1999, LLNL continued to define the extent of TCE in ground water. Four new monitor wells were installed. On April 1, 1998, LLNL submitted the *Characterization Summary Report for the Building 854 Operable Unit* (Ziagos and Reber-Cox 1998c) to the regulatory agencies. On May 28, 1998, LLNL submitted to the regulatory agencies a letter detailing the CERCLA pathway for the operable unit (U.S. Department of Energy 1998d). LLNL installed and began operating a solar-powered portable treatment unit at Building 854 to treat extracted ground water containing VOCs. A second treatment unit will be installed in the future. Several additional wells will be installed during the summer of 2000.

Pit 6 Area

A small ground water TCE plume in a perched terrace alluvium (Qt) water-bearing zone discharges to the surface at small springs at the southeastern edge of the Pit 6 area. The perched water-bearing zone occurs at depths of 0–11 m below ground surface. The source of the TCE plume is the southeast corner of the Pit 6 landfill. The TCE plume is about 200 m long (**Figure 8-19**). Concentrations of VOCs in the plume have declined by more than tenfold since 1992. Current maximum TCE concentrations are about 6.3 ppb. Tritium (at maximum activities of 92.5 Bq/L [2500 pCi/L], nitrate (at maximum concentrations of 228 ppm), and perchlorate (at maximum concentrations of 57 ppb) also occur in the perched water-bearing zone. The lengths of the tritium and perchlorate plumes are 200 and 400 m, respectively. During 1997, a 2.4-acre engineered cap was constructed over the landfill as a CERCLA nontime-critical removal action. During 1998, the *Post-Closure Plan* (Ferry et al. 1998) for the Pit 6 cap was submitted to the regulatory agencies.

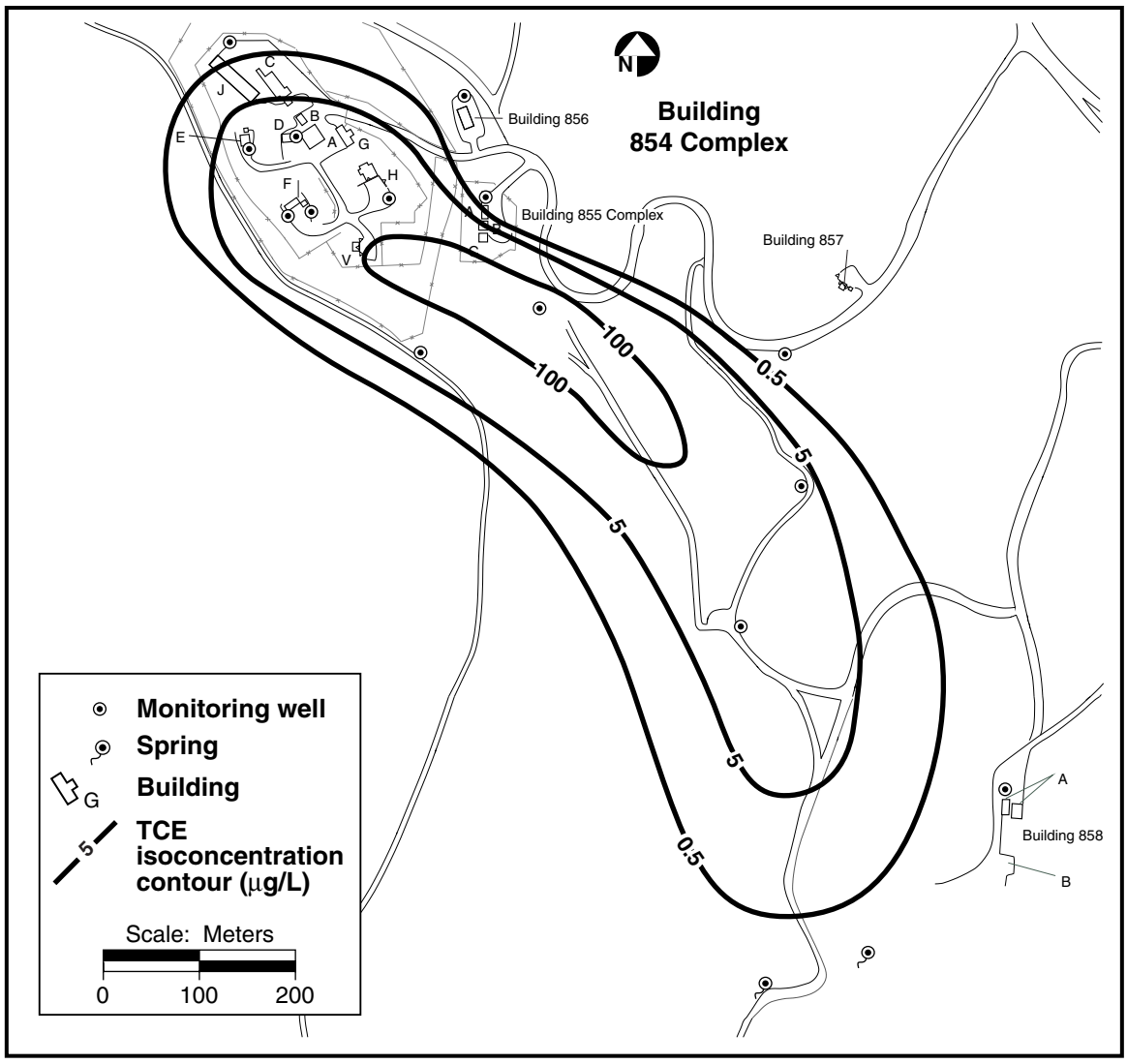


Figure 8-18. Distribution of TCE in ground water in the Building 854 area (second quarter, 1999).

Building 832 Canyon Study Area

At the Building 832 Canyon area (Buildings 830 and 832), solvents were released from weapons component test cells in the past. TCE and nitrate occur in ground water in Qal alluvium and in Neroly Formation sandstone units within $Tnsc_1$ silty-claystone strata 15–25 m beneath the Building 832 Canyon Study Area at maximum 1999 concentrations of 8000 ppb and 174 ppm, respectively. The TCE plume emanates from both the Building 830 and 832 areas and is about 1300 m long (**Figure 8-20**). Perchlorate has also been detected at a maximum concentration of 51 μg/L. Well drilling during 1999

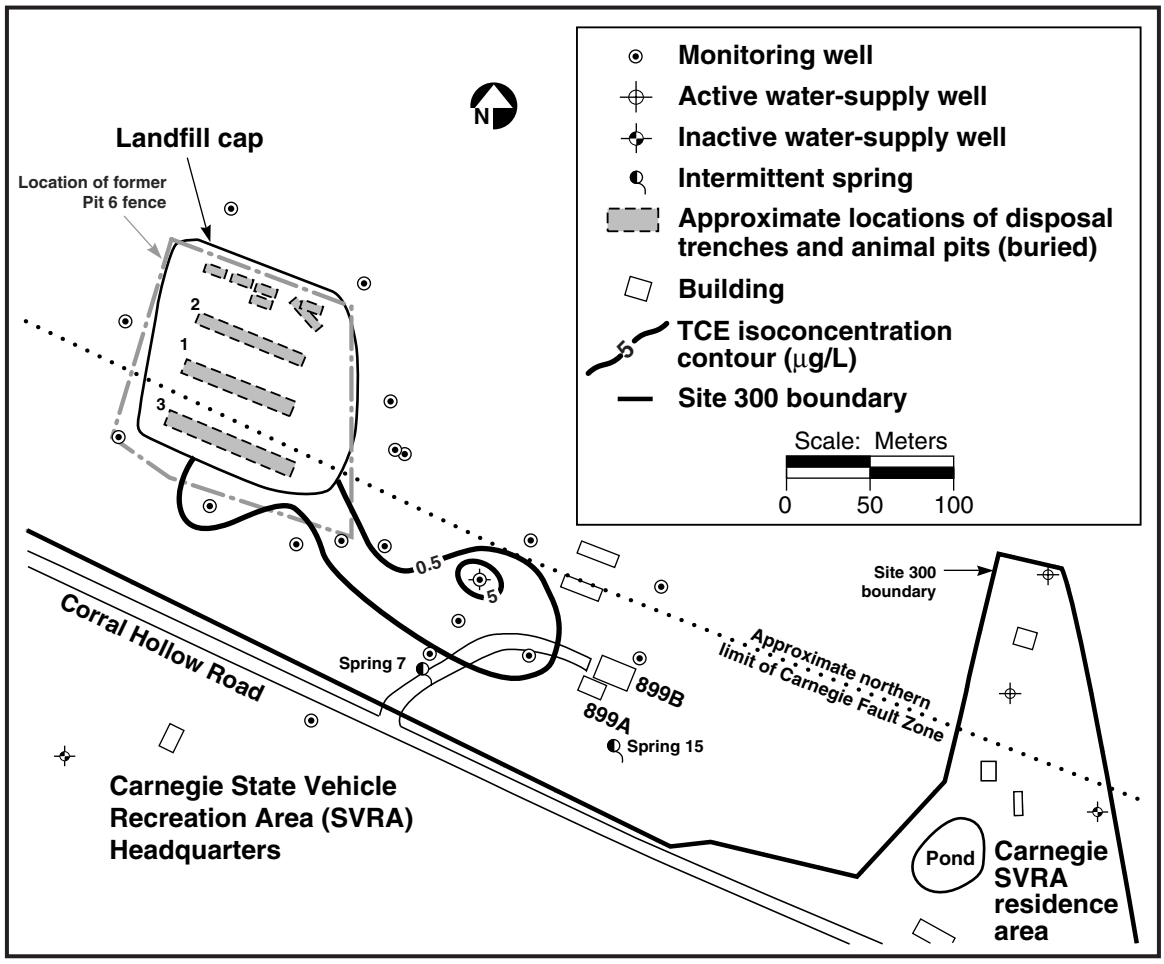


Figure 8-19. Distribution of TCE in ground water in the Pit 6 area (fourth quarter, 1999).

indicated that the TCE contaminant plume and the nitrate in ground water, both emanating from the Building 832 complex, are likely merging with the TCE and nitrate in ground water from the Building 830 area. Perchlorate has also been detected in ground water samples from 15 monitor wells in the area.

In 1999, LLNL linked ten wells in the Building 832 complex, near the suspected test cell release sites, to the Building 832-TF1 for vapor and ground water extraction and treatment and completed construction of the treatment system. LLNL also plans to use innovative, environmentally friendly (green) technologies to treat ground water in the Building 832 Canyon area. A DOE Technology Deployment Initiative (TDI) using iron filings as a treatment system for TCE is in the design and testing phase.

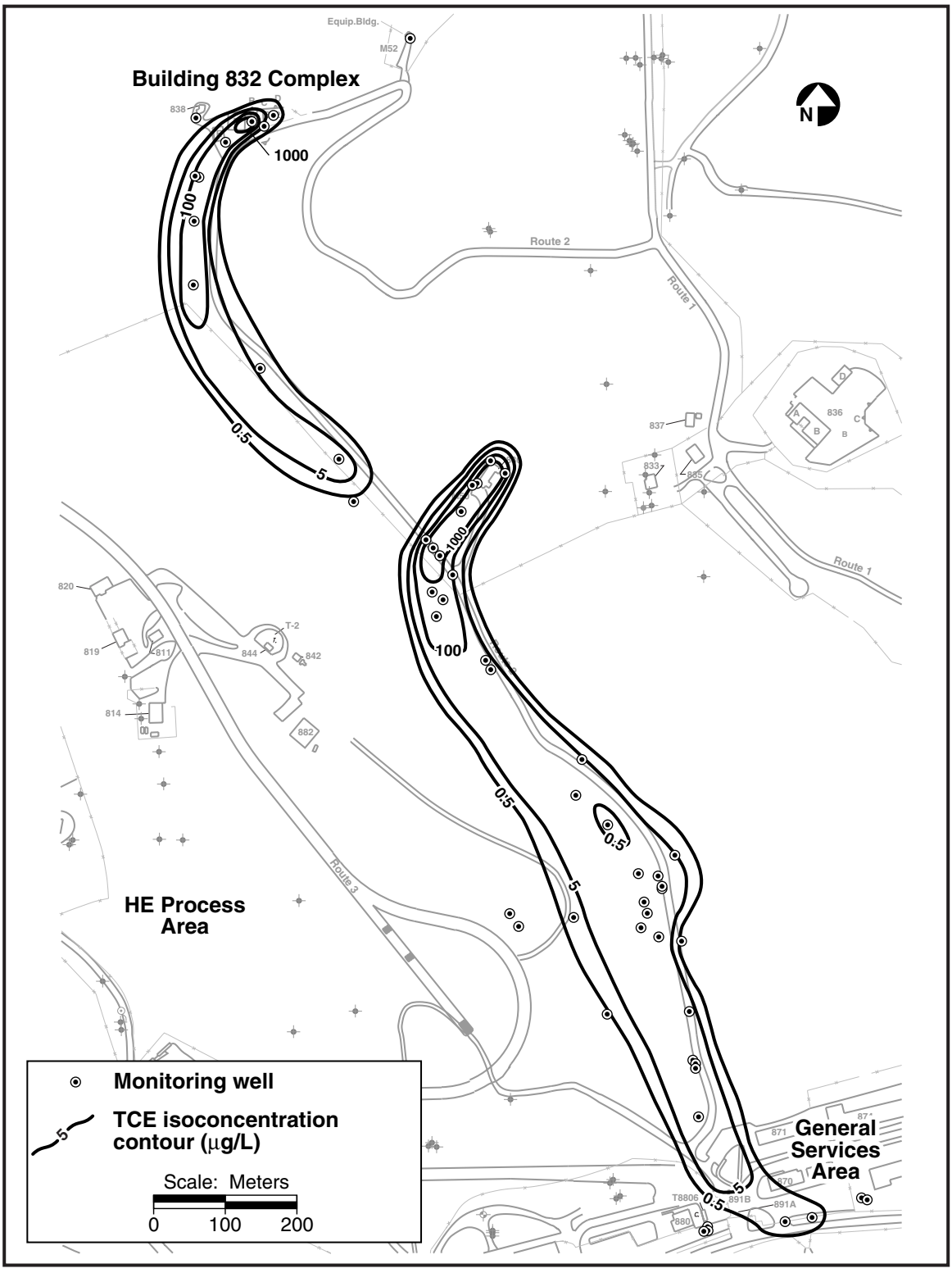


Figure 8-20. Distribution of TCE in ground water in the Building 832 Canyon (fourth quarter, 1999).

Environmental Remediation at Site 300

Dedicated ground water and soil vapor extraction and treatment facilities exist at the eastern GSA, central GSA, and Building 834 areas. During 1999, portable ground water treatment systems were installed at the Building 815 (HE Process Area) and Building 854 areas. A combined soil vapor and ground water treatment system was installed in the Building 832 Canyon Area. The central GSA, eastern GSA and Building 815 treatment facilities discharge to surface drainage courses. The other treatment systems discharge to air. **Table 8-5** summarizes calendar year 1999 and cumulative totals of volumes and masses of contaminants removed from ground water and soil vapor at Site 300. Also in 1999, treatment facility construction, design, and treatability testing activities continued at the High Explosives Process Area and the Building 832 Canyon area.

Table 8-5. Volatile organic compounds (VOCs) removed from ground water and soil vapor at Site 300.

Treatment area	Startup date	1999		Cumulative total	
		Water treated (ML)[a]	VOCs removed (kg)	Water treated (ML)[a]	VOCs removed (kg)
General Services Area					
Eastern GWTF[b]	1991	79.4	0.26	557.4	5.86
Central GWTF	1993	4.16	1.04	8.96	7.54
Building 834	1995	0.169	5.45	0.584	24.7
Building 815	1999	0.34	0.01	0.34	0.01
Building 832	1999	32.4	0.004	32.4	0.004
Building 854	1999	0.189	0.04	0.189	0.04
Pit 6	1998	—[c]	—[c]	0.268	0.0014
		Soil vapor treated (m^3)	**VOCs removed (kg)**	**Soil vapor treated (m^3)**	**VOCs removed (kg)**
General Services Area					
Central	1994	489,078	4.24	1,492,743	64.62
Building 834	1998	390,415	27.58	439,605	34.9
Building 832	1999	3,385.9	0.374	3,385.9	0.374

a ML = 1 million liters.

b GWTF = Ground water treatment facility.

c Pit 6 is not routinely used for ground water treatment. A hydraulic pump test was conducted there in 1998.

General Services Area

The Remedial Design Document for the GSA Operable Units was submitted to the regulatory agencies in 1998. During 1999, the soil vapor extraction and treatment system in the central GSA dry-well source area was consistently operated and maintained to reduce

VOC concentrations in soil vapors, remediate dense nonaqueous-phase liquids in the soil, and mitigate the VOC inhalation risk inside Building 875. The ground water extraction and treatment systems in the central and eastern GSA area were consistently operated and maintained to reduce VOC concentrations in the ground water to drinking water maximum contaminant levels (MCLs), prevent further migration of the contaminant plume, and dewater the shallow water-bearing zone in the Building 875 dry-well area to enhance soil vapor extraction. Wells W-7Q, W-7R, W-7S, and W-7T were installed within the central GSA as monitor wells. These wells are being considered as possible extraction wells for the expansion of the ground water treatment facility. Based on the NPDES permit five-year review, sampling requirements were reduced at the eastern GSA groundwater treatment facility.

The eastern GSA treatment facility employs granular activated carbon (GAC) canisters to remove VOCs from extracted ground water. Extracted central GSA ground water is run through an air-sparging PTU to remove VOCs. Extracted soil vapor at the central GSA is run through GAC canisters to remove VOCs.

Ground water treated at the eastern GSA ground water treatment facility was discharged off site to Corral Hollow Creek, in accordance with NPDES Permit No. CA0082651. **Table 8-5** shows the amount of the water treated and VOCs removed at the eastern GSA. The length of the eastern GSA TCE plume with concentrations over the cleanup standard of 5 ppb (MCL) has been reduced by more than 1400 m. The off-site portion of the plume now extends 200 m beyond the site boundary. TCE concentrations in influent from the eastern GSA ground water treatment system were reduced from 64 ppb in January 1992 to 3 ppb in November 1999. No longer do any off-site wells in the eastern GSA yield ground water TCE concentrations in excess of the cleanup standard of 5 ppb (MCL). LLNL estimates that 2 more years of ground water extraction and treatment will be required to achieve and maintain ground water VOC concentrations below MCLs at the eastern GSA.

At the central GSA, treated ground water was collected and batch-discharged in a remote Site 300 canyon, in accordance with the substantive requirement for wastewater discharge. TCE concentrations in central GSA ground water treatment system (GWTS) influent have been reduced from 9400 ppb in 1993 to 58 ppb in 1999. Volumes of water extracted and masses of VOCs removed from Central GSA ground water are tabulated in **Table 8-5**.

Four quarterly reports were submitted to the EPA and RWQCB in 1999 that detail the performance of the treatment facilities (Lamarre 1999a, b, c, and d). During 1999, the ground water extraction system at the central GSA was expanded to further contain the contaminant plume, increase mass removal, and eliminate contaminant sources as part

of a regulatory-driven milestone. Two monitoring wells located at known contaminant sources and one monitoring well located downgradient of the source were converted to extraction wells. With the increased flow, the existing treatment system was converted and upgraded from batch mode to continuous flow operation.

Following dewatering of bedrock through ground water extraction, soil vapor extraction and treatment of VOCs began in 1994. **Table 8-5** shows the amounts of soil vapor treated and VOCs removed at the central GSA. From 1994 through the end of 1998, VOC concentrations in the central GSA soil vapor extraction influent stream were reduced from 450 parts per million by volume (ppmv) to 2.3 ppmv. VOC concentrations in individual central GSA soil vapor extraction wells have also been significantly reduced.

The central GSA ground water treatment system is operating under substantive requirements for wastewater discharge issued by the Central Valley RWQCB. The central GSA treatment facility discharges to bedrock in the eastern GSA canyon, where the water percolates into the ground. The eastern GSA ground water treatment system operates under NPDES Permit No. CA0082651, issued by the Central Valley RWQCB for discharges into Corral Hollow Creek. The system operated under WDR91-052 until December 5, 1997, when WDR 97-242 was issued. Permit requirements for the central and eastern GSA ground water treatment system are listed in **Table 8-6**. Both the central and eastern GSA treatment systems operated in compliance with regulatory requirements during 1999. LLNL submitted quarterly reports for the GSA treatment systems to the California EPA and the RWQCB in accordance with the National Pollutant Discharge Elimination System Order No. 97-242 for the eastern GSA and the Substantive Requirements for Waste Discharge for the Central GSA (Lamarre 1999a, b, c, and d).

With the increased flow caused by the central GSA well field expansion, the existing treatment system was converted and upgraded from batch mode to continuous flow operation. An additional interlock was added to stop ground water extraction from all wells with pneumatic and electrical pumps during system shutdown. A new vortex meter was installed at the soil vapor extraction and treatment system to more accurately measure extracted air flow. A new 1000-gallon polyethylene effluent surge tank with liquid level switches replaced the Baker tank at the central GSA ground water extraction and treatment system.

Table 8-6. General Services Area ground water treatment system surface discharge permit requirements.

Parameter	Treatment facility	
	Central General Services Area	**Eastern General Services Area**
VOCs	Halogenated and aromatic VOCs	Halogenated VOCs
Maximum daily	5.0 µg/L	5.0 µg/L
Monthly median	0.5 µg/L	0.5 µg/L
Dissolved oxygen	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.
pH (pH units)	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units.	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units.
Temperature	No alteration of ambient receiving water conditions more than 3°C.	No alteration of ambient receiving water conditions more than 3°C.
Place of discharge	To ground water during dry weather and to surface water drainage course in eastern GSA canyon during wet weather.	Corral Hollow Creek.
Flow rate	272,500 L (30-day average daily dry weather maximum discharge limit).	272,500 L per day.
Mineralization	Mineralization must be controlled to no more than a reasonable increment.	Mineralization must be controlled to no more than a reasonable increment.
Methods and detection limits for VOCs	EPA Method 601—detection limit of 0.5 µg/L. EPA Method 602—method detection limit of 0.3 µg/L.	EPA Method 601—detection limit of 0.5 µg/L.

Building 834 Complex

In 1999, the GWTS was operated at full scale. The system was automated to allow for 24-hour operation, in effect switching from a 5-day, 10-hour schedule, to around-the-clock operation for the five weekdays. The soil vapor extraction system tripled the mass removal at the site over 1998 by extracting an additional 7 kg of VOCs from the subsurface. To increase the effectiveness of the treatment system even more, LLNL expanded the extraction wellfield in 1999 by converting a number of monitoring wells into combined ground water and soil vapor extraction wells.

During 1999, there was a 357% increase in overall VOC mass removal over the removal in 1998. During 1998 the combined ground water and soil vapor VOC mass removal at Building 834 was 10.93 kg. During 1999, the combined VOC mass removal at Building 834 was 39.03 kg, of which 6 kg of VOCs were destroyed by in situ microbially mediated

reductive dehalogenation. The LLNL team working on Building 834 remediation received $210,000 in additional funding to study the applicability of in situ bioremediation as a treatment technology (Ziagos et al. 1999). A peer-reviewed publication reported on the novel microbial process that exploits alkoxysiloxane lubricants as drivers for TCE bioattenuation at Building 834 (Halden et al. 1999).

Table 8-5 shows the amounts of water treated and VOCs removed at Building 834. Quarterly reports for the Building 834 treatment facility were submitted to the California EPA and the RWQCB in accordance with the Substantive Requirements for Waste Discharge (Lamarre 1999e, f, g, and h). Because treated ground water is discharged to misters and is not discharged to the ground, there are no treatment system surface discharge permit requirements for Building 834.

High Explosives Process Area

The final *Action Memorandum for the Building 815 Operable Unit Removal Action at Lawrence Livermore National Laboratory Site 300* (Ziagos and Jakub 1998) was submitted to the regulatory agencies on August 17, 1998. This report describes the main components of the removal action, estimates removal action costs, and addresses all verbal and written comments submitted by the community during the public workshop. The *Building 815 Removal Action Design Workplan for the High Explosives Process Area at Lawrence Livermore National Laboratory Site 300* (Ziagos and Reber-Cox 1998a) was submitted to the regulatory agencies on November 15, 1998. This report describes the removal action in more detail and provides a contingency plan to address foreseeable problems that may arise during this removal action.

Treatability testing began in 1998 to evaluate cost-effective ground water treatment technologies for the second phase of ground water cleanup. Removal and destruction technologies are being considered to remediate nitrates and HE compounds, including perchlorate. These technologies use granular-activated carbon, ion-exchange, or electromigration for contaminant removal and ex-situ bioremediation for contaminant destruction. Phytoremediation, using indigenous grasses, is also being evaluated for treating nitrate-bearing ground water.

In 1999, a ground water treatment facility (B815-TF1) was installed near the Site 300 boundary to prevent off-site migration of VOCs in ground water. Using granular-activated carbon, the system pumps and treats water from two existing ground water monitoring wells. Depending on the performance from these two wells, additional wells may be added. **Table 8-5** shows amounts of water treated and VOCs removed in the treatment system.

Pit 6 Landfill Area

The volume of water extracted and TCE mass removed during a hydraulic pump test at Pit 6 is tabulated in **Table 8-5**. The test ran from October 11 to December 3, 1998. The water was treated at an adjacent portable treatment unit using granular activated carbon.

Building 854 Area

In December 1999, a ground water treatment facility (B854-TF1) was installed near the TCE source area at Building 854F as a part of a ground water treatability study. The facility uses granular activated carbon to treat ground water and operates under draft waste discharge requirements. **Table 8-5** shows amounts of water treated and VOCs removed in the treatment system. Treated ground water is misted to air. A second facility will begin operation in the future.

Building 832 Canyon

The first step toward TCE mass removal in the operable unit (OU) was completed with the submittal and acceptance of the Building 832 Canyon OU Treatability Study Workplan in November 1997. This workplan set forth plans for ground water and soil vapor TCE extraction and treatment in 1999 and beyond, using portable treatment units, solar-powered water activated-carbon treatment units, and soil vapor extraction systems. Also under consideration is the use of a subsurface iron filings permeable reactive treatment wall in the lower canyon area to intercept the TCE-laden ground water, destroy the TCE and degradation products, and help control the migration of the TCE plume off site. In October 1999, the Building 832 Canyon ground water and soil vapor treatment system, B832-TF1, began continuous operation. This facility is operating under draft waste discharge requirements. **Table 8-5** shows volume of water treated and mass of VOCs removed in the treatment system. The treated water is discharged into the canyon.

Community Relations

During 1999, LLNL met three times with members of Tri-Valley Citizens Against a Radioactive Environment and their technical advisor as part of the activities funded by an EPA Technical Assistance Grant. A public workshop for the *Draft Site-Wide Feasibility Study* (Ferry et al. 1999) was held on March 23, 1999. A public workshop for the *Draft Site-Wide Proposed Plan* (Dresen et al. 1999) was held on December 30, 1999.